

FINAL TREATABILITY STUDIES PLAN



Environmental Restoration Program

August 26, 1991

**U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado**

Volume II - Appendixes

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By F. J. Curran *(signature)*

Date 8-28-91

ROCKY FLATS PLANT
SITEWIDE TREATABILITY STUDIES PLAN
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ACRONYMS AND ABBREVIATIONS

AEC	U.S. ATOMIC ENERGY COMMISSION
ARARs	APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS
AWQC	AMBIENT WATER QUALITY CRITERIA
BDAT	BEST DEMONSTRATED AVAILABLE TECHNOLOGY
CDH	COLORADO DEPARTMENT OF HEALTH
CEARP	COMPREHENSIVE ENVIRONMENTAL ASSESSMENT & RESPONSE PROGRAM
CERCLA	COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT OF 1980
CFR	CODE OF FEDERAL REGULATIONS
CMS/FS	CORRECTIVE MEASURES STUDY/FEASIBILITY STUDY
CWA	CLEAN WATER ACT
DOE	DEPARTMENT OF ENERGY
DOT	DEPARTMENT OF TRANSPORTATION
DQO	DATA QUALITY OBJECTIVE
DTPA	DIETHYLENETRIAMINEPENTAACETIC ACID
EDTA	ETHYLENEDIAMINETETRAACETIC ACID
EPA	U.S. ENVIRONMENTAL PROTECTION AGENCY
EM	ENVIRONMENTAL MANAGEMENT DEPARTMENT
ER	ENVIRONMENTAL RESTORATION
ERDA	ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
FSP	FIELD SAMPLING PLAN
GAC	GRANULAR ACTIVATED CARBON
HEA	HUMAN HEALTH & ENVIRONMENTAL ASSESSMENT
HSL	HAZARDOUS SUBSTANCE LIST
HSP	HEALTH AND SAFETY PLAN
IAG	INTER-AGENCY AGREEMENT
IHSS	INDIVIDUAL HAZARDOUS SUBSTANCE SITES
IR	INFRARED RADIATION
ISV	IN-SITU VITRIFICATION
IWT	INTERNATIONAL WASTE TECHNOLOGIES
KPEG	POTASSIUM POLYETHYLENE GLYCOLATE
MCL	MAXIMUM CONTAMINANT LEVEL
MCLG	MAXIMUM CONTAMINANT LEVEL GOALS
NEPA	NATIONAL ENVIRONMENTAL POLICY ACT
NPDES	NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM
NRC	NUCLEAR REGULATORY COMMISSION
O&M	OPERATIONS AND MAINTENANCE
OU	OPERABLE UNIT
OUR	OXYGEN UPTAKE RATE
PACT	POWDERED ACTIVATED CARBON TREATMENT
PCB	POLYCHLORINATED BIPHENYL
PCDD	POLYCHLORINATED DIBENZODIOXINS
PCE	TETRACHLOROETHYLENE
PNA	POLYNUCLEAR AROMATIC HYDROCARBONS
QAA	QUALITY ASSURANCE ADDENDUM
QAPP	QUALITY ASSURANCE PROGRAM PLAN
QAPjP	QUALITY ASSURANCE PROJECT PLAN

ACRONYMS AND ABBREVIATIONS
(Concluded)

QA/QC	QUALITY ASSURANCE/QUALITY CONTROL
RCRA	RESOURCE CONSERVATION AND RECOVERY ACT
RF	RADIO FREQUENCY
RFEDS	ROCKY FLATS ENVIRONMENTAL DATA SYSTEM
RFI	RCRA FACILITY INVESTIGATION
RFP	ROCKY FLATS PLANT
RI	REMEDIAL INVESTIGATION
RO	REVERSE OSMOSIS
ROD	RECORD OF DECISION
SARA	SUPERFUND AMENDMENTS & REAUTHORIZATION ACT
SDWA	SAFE DRINKING WATER ACT
SOP	STANDARD OPERATING PROCEDURE
SOW	STATEMENT OF WORK
SWMU	SOLID WASTE MANAGEMENT UNITS
TAL	TARGET ANALYTE LIST
TBC	TO-BE-CONSIDERED
TBP	TRIBUTYL PHOSPHATE
TCE	TRICHLOROETHYLENE
TCL	TARGET COMPOUND LIST
TCLP	TOXICITY CHARACTERISTICS LEACHING PROCEDURE
TDS	TOTAL DISSOLVED SOLIDS
TRU	TRANSURANIC
TS	TREATABILITY STUDY
TSP	TREATABILITY STUDIES PLAN
TSDF	TREATMENT, STORAGE, OR DISPOSAL FACILITY
UMTRA	URANIUM MILL TAILING REMEDIAL ACTION
USPS	UNITED STATES POSTAL SERVICE
UV	ULTRAVIOLET
VOC	VOLATILE ORGANIC COMPOUNDS
WQC	WATER QUALITY CRITERIA
WQCC	WATER QUALITY CONTROL COMMISSION

APPENDIX A
POTENTIAL ARARS FOR THE SITEWIDE
TREATABILITY STUDIES PROGRAM

APPENDIX A
POTENTIAL ARARS FOR THE SITEWIDE
TREATABILITY STUDIES PROGRAM

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TABLE A-1

**POTENTIAL SITE-WIDE CHEMICAL-SPECIFIC ARARS/TBCs
GROUNDWATER QUALITY STANDARDS**

Parameter	Type	FEDERAL STANDARDS					STATE STANDARDS (TBCs)				
		SDWA	SDWA	SDWA	SDWA	RCRA	CDH WQCC Groundwater Quality Standards (d)				
		Maximum Contaminant Level	Maximum Contaminant Level	Maximum Contaminant Level	Maximum Contaminant Level	Subpart F Concentration Limit	Tables A & B	Table 1 Human Health	Table 2 Secondary Drinking	Table 3 Agricultural	Table 4 TDS Standard
		(a)	(b)	(a)	(a)	(c)	Statewide				
Disolved Oxygen	Field Parameter										
pH	Field Parameter	6.5–8.5 *						6.5–8.5	6.5–8.5		
Specific Conductance	Field Parameter										
Temperature	Field Parameter										
Total Dissolved Solids	Indicator	500 mg/l *									400 mg/l (1)
Bicarbonate	Anion										
Carbonate	Anion										
Chloride	Anion	250 mg/l *						250 mg/l			
Fluoride	Anion	4 mg/l, 2 mg/l*		4 mg/l				4 mg/l		2 mg/l	
N as Nitrate	Anion	10 mg/l						10.0 mg/l			
N as Nitrate+Nitrite	Anion		10 mg/l					10 mg/l		100 mg/l	
N as Nitrite	Anion		1 mg/l					1.0 mg/l		10 mg/l	
Potassium	Anion										
Sulfate	Anion	250 mg/l *							250 mg/l		
Aluminum	Metal			0.05 to 0.2 mg/l*						5.0 mg/l	
Antimony	Metal										
Arsenic	Metal	50 ug/l						50 ug/l		100 ug/l	
Arsenic III	Metal										
Arsenic V	Metal										
Barium	Metal	1.0 mg/l						1.0 mg/l			
Beryllium	Metal										
Cadmium	Metal	10 ug/l	5 ug/l					10 ug/l		100 ug/l	
Calcium	Metal									10 ug/l	

TABLE A-1

**POTENTIAL SITE-WIDE CHEMICAL-SPECIFIC ARARS/TBCs
GROUNDWATER QUALITY STANDARDS**

		FEDERAL STANDARDS					STATE STANDARDS (TBCs)				
Parameter	Type	SDWA	SDWA	SDWA	SDWA	RCRA	CDH WQCC Groundwater Quality Standards (d)				
		Maximum Contaminant Level	Maximum Contaminant Level	Maximum Contaminant Level	Maximum Contaminant Level	Subpart F Concentration Limit	Tables				
		(a)	(b)	(a)	(a)	(c)	A & B Statewide	Table 1 Human Health	Table 2 Secondary Drinking	Table 3 Agricultural	Table 4 TDS Standard
Chromium	Metal	50 ug/l	100 ug/l		100 ug/l	50 ug/l		50 ug/l		100 ug/l	
Chromium III	Metal										
Chromium VI	Metal										
Cobalt	Metal										
Copper	Metal	1 mg/l *							1 mg/l	50 ug/l	200 ug/l
Cyanide	Metal							200 ug/l			
Iron	Metal	300 ug/l *							300 ug/l	5 mg/l	
Lead	Metal	50 ug/l				50 ug/l		50 ug/l		100 ug/l	
Magnesium	Metal										
Manganese	Metal	50 ug/l *							50 ug/l	200 ug/l	
Mercury	Metal	2 ug/l			2 ug/l			2 ug/l		10 ug/l	
Molybdenum	Metal										
Nickel	Metal									200 ug/l	
Selenium	Metal	10 ug/l	50 ug/l		50 ug/l			10 ug/l		20 ug/l	
Silver	Metal	50 ug/l	100 ug/l *					50 ug/l			
Sodium	Metal										
Thallium	Metal										
Tin	Metal										
Titanium	Metal										
Tungsten	Metal										
Vanadium	Metal										
Zinc	Metal	5 mg/l *							5 mg/l	100 ug/l	2.0 mg/l
Americium 241	Radionuclide										
Cesium 137	Radionuclide										

TABLE A-1

**POTENTIAL SITE-WIDE CHEMICAL-SPECIFIC ARARS/TBCs
GROUNDWATER QUALITY STANDARDS**

FEDERAL STANDARDS										STATE STANDARDS (TBCs)			
Parameter	Type	SDWA	SDWA	SDWA	SDWA	RCRA	CDH WQCC Groundwater Quality Standards (d)						
		Maximum Contaminant Level	Maximum Contaminant Level	Maximum Contaminant Level	Maximum Contaminant Level	Subpart F Concentration Limit	Table 1	Table 2	Table 3	Table 4			
		(a)	(b)	(a)	(b)	(c)	A & B	Human Health	Secondary Drinking	Agricultural	TDS Standard		
Cesium 134	Radionuclide							80 pCi/l (2)					
Gross Alpha	Radionuclide	15 pCi/l							15 pCi/l				
Gross Beta	Radionuclide	4 mrem/yr (50 pCi/l)							4 mrem/yr				
Plutonium 238+239+240	Radionuclide												
Radium 226+228	Radionuclide	5 pCi/l						15 pCi/l (2)					
Strontium 90	Radionuclide	8 pCi/l (3)						5 pCi/l (2)					
Thorium 230+232	Radionuclide							8 pCi/l (2)					
Tritium	Radionuclide	20,000 pCi/l (3)						60 pCi/l (2)					
Uranium 233+234	Radionuclide							20,000 pCi/l(2)					
Uranium 235	Radionuclide												
Uranium 238	Radionuclide												
Uranium (total)	Radionuclide												
1,1-Dichloroethane	Volatile												
1,1-Dichloroethene	Volatile	7 ug/l		7 ug/l				7 ug/l					
1,1,1-Trichloroethane	Volatile	200 ug/l		200 ug/l				200 ug/l					
1,1,2,2-Tetrachloroethane	Volatile												
1,1,2-Trichloroethane	Volatile							28 ug/l					
1,2-Dichloroethane	Volatile	5 ug/l		0 ug/l				5 ug/l					
1,2-Dichloroethene (cis)	Volatile		70 ug/l		70 ug/l			70 ug/l					
1,2-Dichloroethene (trans)	Volatile		100 ug/l		100 ug/l			70 ug/l					
1,2-Dichloropropane	Volatile		5 ug/l		0 ug/l			560 ng/l					
2-Butanone	Volatile												
2-Hexanone	Volatile												

TABLE A-1

POTENTIAL SITE-WIDE CHEMICAL-SPECIFIC ARARS/TBCs
GROUNDWATER QUALITY STANDARDS

Parameter	Type	FEDERAL STANDARDS					STATE STANDARDS (TBCs)				
		SDWA Maximum Contaminant Level	SDWA Maximum Contaminant Level	SDWA Maximum Contaminant Level	SDWA Maximum Contaminant Level	RCRA Subpart F Concentration Limit (40 CFR 264.94) (c)	Tables A & B Statewide	Table 1 Human Health	Table 2 Secondary Drinking	Table 3 Agricultural	Table 4 TDS Standard
4-Methyl-2-pentanone	Volatile										
Acetone	Volatile										
Benzene	Volatile	5 ug/l			0 mg/l					5 ug/l	
Benzo(a)anthracene	Volatile										
Benzo(a)pyrene	Volatile										
Benzo(b)fluoranthene	Volatile										
Benzo(g,h,i)perylene	Volatile										
Benzo(k)fluoranthene	Volatile										
Bromodichloromethane	Volatile										
Bromoform	Volatile										
Bromomethane	Volatile										
Chlorinated Benzenes	Volatile										
Chlorobenzene (mono)	Volatile		0.1 mg/l		0.1 mg/l					300 ug/l	
Chloroethane	Volatile										
Chloroform	Volatile	Tot THM** <100 ug/l								Tot THM** <100 ug/l	
Chloromethane	Volatile										
cis-1,3-Dichloropropene	Volatile										
Dibromochloromethane	Volatile										
Ethyl Benzene	Volatile		0.7 mg/l		0.7 mg/l					680 ug/l	
Fluoranthene	Volatile										
Haloethers	Volatile										
Halomethanes	Volatile										
Indeno(1,2,3-cd)pyrene	Volatile										

TABLE A-1

POTENTIAL SITE-WIDE CHEMICAL-SPECIFIC ARARS/TBCs
GROUNDWATER QUALITY STANDARDS

Parameter	Type	FEDERAL STANDARDS					STATE STANDARDS (TBCs)				
		SDWA		SDWA		RCRA	SDWA		CDH WQCC Groundwater Quality Standards (d)		
		Maximum Contaminant Level	Maximum Contaminant Level	Maximum Contaminant Level	Maximum Contaminant Level	Subpart F Concentration Limit	Maximum Contaminant Level	Goal	Table 1 Human Health	Table 2 Secondary Drinking	Table 3 Agricultural
		(a)	(b)	(a)	(a)	(c)	(b)	(a)	Statewide A & B	Drinking	TDS Standard
Methylene Chloride	Volatile										
Phenanthrene	Volatile										
Phenol	Volatile										
Polynuclear Aromatic Hydrocarbons	Volatile										
Pyrene	Volatile										
Styrene	Volatile		0.1 mg/l				0.1 mg/l				1 ug/l
Tetrachloroethanes	Volatile										
Tetrachloroethene	Volatile		5 ug/l				0 ug/l			10 ug/l	
Total Xylenes	Volatile		10 mg/l				10 mg/l				
trans-1,3-Dichloropropene	Volatile										
Trichloroethanes	Volatile										
Trichloroethene	Volatile	5 ug/l			0 ug/l					5 ug/l	
Vinyl Acetate	Volatile										
1,2-Dichlorobenzene (ortho)	Semi-Volatile		0.6 mg/l				0.6 mg/l			620 ug/l	
1,3-Dichlorobenzene (meta)	Semi-Volatile									620 ug/l	
1,4-Dichlorobenzene (para)	Semi-Volatile	75 ug/l			75 ug/l					75 ug/l	
1,2,4-Trichlorobenzene	Semi-Volatile										
2-Chloronaphthalene	Semi-Volatile										
2-Chlorophenol	Semi-Volatile										
2-Methylnaphthalene	Semi-Volatile										
2-Methylphenol	Semi-Volatile										
2-Nitroaniline	Semi-Volatile										
2-Nitrophenol	Semi-Volatile										

TABLE A--1

POTENTIAL SITE-WIDE CHEMICAL-SPECIFIC ARARS/TBCs
GROUNDWATER QUALITY STANDARDS

Parameter	Type	FEDERAL STANDARDS					STATE STANDARDS (TBCs)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
		SDWA Maximum Contaminant Level (a)	SDWA Maximum Contaminant Level		SDWA Maximum Contaminant Level (b)	SDWA Maximum Contaminant Level (c)	RCRA Subpart F Concentration Limit (40 CFR 264.94)	CDH WQCC Groundwater Quality Standards (d)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
			TBCs (b)	Goal (a)				Goal (a)	TBCs (b)	Tables A & B	Table 1 Human Health	Table 2 Secondary Drinking	Table 3 Agricultural	Table 4 TDS Standard																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
2,4-Dichlorophenol	Semi-Volatile																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					

POTENTIAL SITE-WIDE CHEMICAL-SPECIFIC ARARS/TBCS GROUNDWATER QUALITY STANDARDS

EG&G/SP/22499/R2TA-1.WK1 05-16-91/LOTUS/WP/22499

POTENTIAL SITE-WIDE CHEMICAL-SPECIFIC ARARs/TBCs
GROUNDWATER QUALITY STANDARDS

EG&G/TSP/22499/R2TA-1.WK1 05-16-91/LOTUS/WP/22499

POTENTIAL SITE-WIDE CHEMICAL-SPECIFIC ARARS/TBCS GROUNDWATER QUALITY STANDARDS

EXPLANATION OF TABLE

** = total trihalomethanes: chloroform, bromoform, bromodichloromethane, dibromochloromethane

WQCC = Water Quality Control Commission

(d) CDH/Water Quality Control Commission The Basic Standards for Ground Water, 3.11.0 (5 CCR 1002-8) 1/5/1987 amended 9/11/1990

TABLE A-2

POTENTIAL SITE WIDE CHEMICAL-SPECIFIC ARARS
FEDERAL SURFACE WATER QUALITY STANDARDS

Parameter	Type	SDWA			SDWA			SDWA			CWA			CWA		
		Maximum Contaminant Level	TBCs	Goal	Level	Maximum Contaminant Level	Goal	TBCs (b)	Level	Maximum Contaminant Level	AWQC for Protection of Aquatic Life (c)		Protection of Human Health (c)		Water Quality Criteria for Fish Consumption	
											Value	Acute Value	Chronic Value	Ingestion	Fish	Only
Disolved Oxygen	Field Parameter										5.0 mg/l					
pH	Field Parameter	6.5-8.5 *									6.5-9					
Specific Conductance	Field Parameter															
Temperature	Field Parameter															
Total Dissolved Solids	Indicator	500 mg/l *														
Bicarbonate	Anion															
Carbonate	Anion															
Chloride	Anion	250 mg/l *														
Flouride	Anion	4 mg/l, 2 mg/l *														
N as Nitrate	Anion	10 mg/l														
N as Nitrate+Nitrite	Anion															
N as Nitrite	Anion															
Potassium	Anion															
Sulfate	Anion	250 mg/l *														
Aluminum	Metal															
Antimony	Metal															
Arsenic	Metal	50 ug/l														
Arsenic III	Metal															
Arsenic V	Metal															
Barium	Metal	1 mg/l														
Beryllium	Metal															
Cadmium	Metal	10 ug/l														
Calcium	Metal															
Chromium	Metal	50 ug/l														
Chromium III	Metal															
Chromium VI	Metal															
Cobalt	Metal															

TABLE A-2

POTENTIAL SITE WIDE CHEMICAL-SPECIFIC ARARS
FEDERAL SURFACE WATER QUALITY STANDARDS

Parameter	Type	SDWA			SDWA			CWA			CWA		
		Maximum Contaminant Level	TBCs	(a)	Maximum Contaminant Level	TBCs (b)	Goal	AWQC for Protection of Aquatic Life (c)		Acute Value	Protection of Human Health (c)		Fish Consumption Only
Copper	Metal	1 mg/l *						18 ug/l (3)		12 ug/l (3)	Water and Ingestion	Fish	
Cyanide	Metal							22 ug/l		5.2 ug/l	200 ug/l		
Iron	Metal	300 ug/l *								1.0 mg/l	300 ug/l		
Lead	Metal	50 ug/l						82 ug/l (3)		3.2 ug/l (3)	50 ug/l		
Magnesium	Metal												
Manganese	Metal	50 ug/l *											
Mercury	Metal	2 ug/l						2.4 ug/l		12 ng/l	50 ug/l		100 ug/l
Molybdenum	Metal										144 ng/l		148 ng/l
Nickel	Metal												
Selenium	Metal	10 ug/l	50 ug/l					1.4 mg/l (3)		160 ug/l (3)	13.4 ug/l		100 ug/l
Silver	Metal	50 ug/l	100 ug/l *					260 ug/l		36 ug/l	10 ug/l		
Sodium	Metal							4.1 ug/l (3)		120 ng/l	50 ug/l		
Thallium	Metal												
Tin	Metal							1.4 mg/l (1)		40 ug/l (1)	13 ug/l		48 ug/l
Titanium	Metal												
Tungsten	Metal												
Vanadium	Metal												
Zinc	Metal	5 mg/l *						120 ug/l (3)		110 ug/l (3)			
Americium 241	Radionuclide												
Cesium 137	Radionuclide												
Cesium 134	Radionuclide												
Gross Alpha	Radionuclide	15 pCi/l											
Gross Beta	Radionuclide	4 mrem/yr (50 pCi/l)											
Plutonium 238+239+240	Radionuclide												
Radium 226+228	Radionuclide	5 pCi/l											
Strontium 90	Radionuclide	8 pCi/l (5)											
Thorium 230+232	Radionuclide												

TABLE A-2

POTENTIAL SITE WIDE CHEMICAL-SPECIFIC ARARS
FEDERAL SURFACE WATER QUALITY STANDARDS

Parameter	Type	SDWA		SDWA		SDWA		CWA		CWA		CWA	
		Maximum Contaminant Level (a)	Maximum Contaminant Level (b)	Maximum Contaminant Level (a)	Maximum Contaminant Level (b)	AWQC for Protection of Aquatic Life (c)		Water Quality Criteria for Protection of Human Health (c)		Water Quality Criteria for Protection of Human Health (c)			
						Acute Value	Chronic Value	Fish Ingestion	Fish Consumption Only	Fish Ingestion	Fish Consumption Only		
20,000 pCi/l (5)													
Tritium	Radionuclide												
Uranium 233+234	Radionuclide												
Uranium 235	Radionuclide												
Uranium 238	Radionuclide												
Uranium (total)	Radionuclide												
1,1-Dichloroethane	Volatile	7 ug/l		7 ug/l									
1,1-Dichloroethene	Volatile	200 ug/l		200 ug/l									
1,1,1-Trichloroethane	Volatile												
1,1,2,2-Tetrachloroethane	Volatile												
1,1,2-Trichloroethane	Volatile												
1,2-Dichloroethane	Volatile	5 ug/l		0 ug/l				118 mg/l (1)				18.4 mg/l	1.03 g/l
1,2-Dichloroethene (cis)	Volatile		70 ug/l		70 ug/l					2.4 mg/l (1)		170 ng/l**	10.7 ug/l**
1,2-Dichloroethene (trans)	Volatile		100 ug/l		100 ug/l					9.4 mg/l (1)		600 ng/l**	41.8 ug/l**
1,2-Dichloropropane	Volatile		5 ug/l		5 ug/l								
2-Butanone	Volatile							23 mg/l (1)		5.7 mg/l (1)			
2-Hexanone	Volatile												
4-Methyl-2-pentanone	Volatile												
Acetone	Volatile												
Benzene	Volatile	5 ug/l		0 mg/l				5.3 mg/l (1)				660 ng/l**	40 ug/l**
Benzo(a)anthracene	Volatile												
Benzo(a)pyrene	Volatile												
Benzo(b)fluoranthene	Volatile												
Benzo(g,h,i)perylene	Volatile												
Benzo(k)fluoranthene	Volatile												
Bromodichloromethane	Volatile												
Bromoform	Volatile												
Bromomethane	Volatile												

POTENTIAL SITE WIDE CHEMICAL-SPECIFIC ARARS FEDERAL SURFACE WATER QUALITY STANDARDS

Parameter	Type	SDWA		SDWA		SDWA		CWA		CWA	
		Maximum Contaminant Level (a)	Maximum Contaminant Level TBCs (b)	Maximum Contaminant Level Goal (a)	Maximum Contaminant Level Goal TBCs (b)	AWQC for Protection of Aquatic Life (c)		Protection of Human Health (c)			
						Acute Value	Chronic Value	Fish Ingestion	Fish Consumption Only		
Chlorinated Benzenes	Volatile					250 ug/l (1)	50 ug/l (1)				
Chlorobenzene (mono)	Volatile		0.1 mg/l								
Chloroethane	Volatile										
Chloroform	Volatile	Tot THM				28.9 mg/l (1)	1.24 mg/l (4)	0.19 ug/l**		15.7 ug/l **	
Chloromethane	Volatile										
cis-1,3-Dichloropropene	Volatile					6.06 mg/l (1)	244 ug/l (1)	87 ug/l		14.1 mg/l	
Dibromochloromethane	Volatile										
Ethyl Benzene	Volatile		0.7 mg/l		0.7 mg/l	32 mg/l (1)		1.4 mg/l		3.28 mg/l	
Fluoranthene	Volatile					3.98 mg/l (1)		42 ug/l		54 ug/l	
Haloethers	Volatile					380 ug/l (1)	122 ug/l (1)				
Halomethanes	Volatile					11 mg/l (1)		190 ng/l**		15.7 ug/l**	
Indeno(1,2,3-cd)pyrene	Volatile										
Methylene Chloride	Volatile										
Phenanthrene	Volatile										
Phenol	Volatile										
Polynuclear Aromatic Hydrocarbons	Volatile					10.2 mg/l (1)	2.56 mg/l (1)	3.5 mg/l			
Pyrene	Volatile							2.8 ng/l**		31.1 ng/l**	
Styrene	Volatile		0.1 mg/l		0.1 mg/l						
Tetrachloroethanes	Volatile					9.32 mg/l (1)					
Tetrachloroethene	Volatile		5 ug/l		0 ug/l	5.28 mg/l (1)	840 ug/l (1)	800 ng/l**		8.85 ug/l**	
Total Xylenes	Volatile		10 mg/l		10 mg/l						
trans-1,3-Dichloropropene	Volatile					6.06 mg/l (1)	244 ug/l (1)	87 ug/l		14.1 mg/l	
Trichloroethanes	Volatile					18 mg/l (1)					
Trichloroethene	Volatile					45 mg/l (1)	21.9 mg/l (1)	2.7 ug/l**		80.7 ug/l**	
Vinyl Acetate	Volatile	5 ug/l		0 ug/l							
1,2-Dichlorobenzene (ortho)	Semi-Volatile		0.6 mg/l		0.6 mg/l						

TABLE A-2

POTENTIAL SITE WIDE CHEMICAL-SPECIFIC ARARS
FEDERAL SURFACE WATER QUALITY STANDARDS

Parameter	Type	SDWA			SDWA			CWA			CWA		
		Maximum Contaminant Level	Maximum Contaminant Level	Maximum Contaminant Level	TBCs	Goal	TBCs (b)	Acute Value	Chronic Value	Protection of Aquatic Life (c)	Water Quality Criteria for Protection of Human Health (c)		
											Water and Fish Ingestion	Fish Consumption Only	
1,3-Dichlorobenzene (meta)	Semi-Volatile												
1,4-Dichlorobenzene (para)	Semi-Volatile	75 ug/l											
1,2,4-Trichlorobenzene	Semi-Volatile												
2-Chloronaphthalene	Semi-Volatile												
2-Chlorophenol	Semi-Volatile												
2-Methylnaphthalene	Semi-Volatile												
2-Methylphenol	Semi-Volatile												
2-Nitroaniline	Semi-Volatile												
2-Nitrophenol	Semi-Volatile												
2,4-Dichlorophenol	Semi-Volatile												
2,4-Dimethylphenol	Semi-Volatile												
2,4-Dinitrophenol	Semi-Volatile												
2,4-Dinitrotoluene	Semi-Volatile												
2,4,5-Trichlorophenol	Semi-Volatile												
2,4,6-Trichlorophenol	Semi-Volatile												
3-Nitroaniline	Semi-Volatile												
3,3-Dichlorobenzidine	Semi-Volatile												
4-Bromophenyl Phenylether	Semi-Volatile												
4-Chloroaniline	Semi-Volatile												
4-Chlorophenyl Phenyl Ether	Semi-Volatile												
4-Chloro-3-methylphenol	Semi-Volatile												
4-Methylphenol	Semi-Volatile												
4-Nitroaniline	Semi-Volatile												
4-Nitrophenol	Semi-Volatile												
4,6-Dinitro-2-methylphenol	Semi-Volatile												
Acenaphthene	Semi-Volatile												
Acetone	Semi-Volatile												

TABLE A-2

POTENTIAL SITE WIDE CHEMICAL-SPECIFIC ARARS
FEDERAL SURFACE WATER QUALITY STANDARDS

Parameter	Type	SDWA			SDWA			CWA			CWA		
		Maximum Contaminant Level	TBCs	(a)	Maximum Contaminant Level	TBCs (b)	Goal	AWQC for Protection of Aquatic Life (c)			Protection of Human Health (c)		
								Value	Acute Value	Chronic Value	Water and Fish Ingestion	Fish Consumption Only	
Acrylonitrile	Semi-Volatile							7.5 mg/l		2.6 mg/l	0.058 ug/l	0.65 ug/l	
Aldrin	Semi-Volatile							3.0 ug/l			0.074 ng/l	0.079 ng/l	
Atrazine	Semi-Volatile		3 ug/l				3 ug/l						
Benidine	Semi-Volatile							2.5 mg/l			0.12 ng/l	0.53 ng/l	
Benzoic Acid	Semi-Volatile												
Benzyl Alcohol	Semi-Volatile												
bis(2-Chloroethoxy)methane	Semi-Volatile												
bis(2-Chloroethyl)ether	Semi-Volatile										30 ng/l**	1.38 ug/l**	
bis(2-Chloroisopropyl)ether	Semi-Volatile										34.7 ug/l	4.36 mg/l	
bis(2-Ethylhexyl)phthalate	Semi-Volatile										15 mg/l	50 mg/l	
Butyl Benzylphthalate	Semi-Volatile												
Carbon Disulfide	Semi-Volatile												
Carbon Tetrachloride	Semi-Volatile	5 ug/l			0 mg/l			35.2 mg/l (1)			400 ng/l**	6.94 ug/l**	
Chlorinated Benzenes	Semi-Volatile							250 ug/l		50 ug/l			
Chlorinated Ethers	Semi-Volatile												
Chlorinated Naphthalenes	Semi-Volatile							1.6 mg/l (1)					
Chloroalkylethers	Semi-Volatile							238 mg/l (1)					
Chlordane	Semi-Volatile		2 ug/l					2.4 ug/l		4.3 ng/l	0.46 ng/l	0.48 ng/l	
Chlorophenol	Semi-Volatile												
DDT	Semi-Volatile							1.1 ug/l		1.1 ng/l	24 pg/l	24 pg/l	
DDT metabolite (DDE)	Semi-Volatile							1.05 mg/l					
DDT metabolite (TDE)	Semi-Volatile							0.06 ug/l			0.01 ug/l	0.02 ug/l	
Dichlorobenzidine	Semi-Volatile												
Dibenzofuran	Semi-Volatile												
Dibenz(a,h)anthracene	Semi-Volatile												
Dichlorobenzenes	Semi-Volatile							1.12 mg/l (1)		763 ug/l (1)	400 ug/l	2.6 mg/l	
Dichloroethenes	Semi-Volatile							11.6 mg/l (1)			33 ng/l**	1.85 ug/l**	
Dichloromethane	Semi-Volatile												
Dieldrin	Semi-Volatile							2.5 ug/l		1.9 ng/l	0.071 ng/l	76 pg/l	

TABLE A-2

POTENTIAL SITE WIDE CHEMICAL-SPECIFIC ARARS
FEDERAL SURFACE WATER QUALITY STANDARDS

Parameter	Type	SDWA				SDWA				CWA				CWA			
		Maximum Contaminant Level		Maximum Contaminant Level		Maximum Contaminant Level		Maximum Contaminant Level		AWQC for Protection of Aquatic Life (c)		Protection of Human Health (c)		Protection of Human Health (c)		Protection of Human Health (c)	
		(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	Value	Chronic Value	Acute Value	Chronic Value	Fish Ingestion	Fish Consumption	Only	
Diethylphthalate	Semi-Volatile													350 mg/l		1.8 g/l	
Dimethylphthalate	Semi-Volatile													313 mg/l		2.9 g/l	
Di-n-butylphthalate	Semi-Volatile																
Dinitrotoluene	Semi-Volatile																
Di-n-octylphthalate	Semi-Volatile																
Dioxin	Semi-Volatile																
Endosulfan I	Semi-Volatile																
Endosulfan II	Semi-Volatile																
Endosulfan Sulfate	Semi-Volatile																
Endrin	Semi-Volatile	0.2 ug/l															
Endrin Ketone	Semi-Volatile																
Fluorene	Semi-Volatile																
Halomethanes	Semi-Volatile																
Heptachlor	Semi-Volatile	0.10 mg/l															
Heptachlor Epoxide	Semi-Volatile		0.4 ug/l														
Hexachlorobenzene	Semi-Volatile		0.2 ug/l														
Hexachlorobutadiene	Semi-Volatile																
Hexachlorocyclohexane, Alpha	Semi-Volatile																
Hexachlorocyclohexane, Beta	Semi-Volatile																
Hexachlorocyclohexane, Technical	Semi-Volatile																
Hexachlorocyclopentadiene	Semi-Volatile																
Hexachloroethane	Semi-Volatile																
Isophorone	Semi-Volatile																
Methoxychlor	Semi-Volatile																
Naphthalene	Semi-Volatile																
Nitrobenzene	Semi-Volatile																
Nitrophenols	Semi-Volatile																
Nitrosamines	Semi-Volatile																
Nitrosodibutylamine	Semi-Volatile																
Nitrosodiethylamine	Semi-Volatile																

TABLE A-2

**POTENTIAL SITE WIDE CHEMICAL-SPECIFIC ARARS
FEDERAL SURFACE WATER QUALITY STANDARDS**

Parameter	Type	SDWA			SDWA			CWA			CWA		
		Maximum Contaminant Level	Maximum Contaminant Level	Maximum Contaminant Level	Maximum Contaminant Level	Maximum Contaminant Level	Maximum Contaminant Level	AWQC for Protection of Aquatic Life (c)	Protection of Human Health (c)		Protection of Human Health (c)		
		(a)	(b)	(b)	(a)	(b)	(b)	Value	Acute Value	Chronic Value	Water and Ingestion	Fish Consumption	
Nitrosodimethylamine	Semi-Volatile										1.4 ng/l	16 ug/l	
Nitrosopyrrolidine	Semi-Volatile										16 ng/l	91.9 ug/l	
N-Nitrosodiphenylamine	Semi-Volatile										4.9 ug/l **	16.1 ug/l **	
N-Nitroso-di-n-dipropylamine	Semi-Volatile												
PCBs	Semi-Volatile												
Pentachlorinated Ethanes	Semi-Volatile		0.5 ug/l				0 ug/l		2.0 ug/l	14 ng/l	79 pg/l	79 pg/l	
Pentachlorophenol	Semi-Volatile								7.24 mg/l (1)	1.1 mg/l (1)			
Phthalate Esters	Semi-Volatile								20 ug/l (4)	13 ug/l (4)	1.01 mg/l		
Simazine	Semi-Volatile								940 ug/l (1)	3 ug/l (1)			
Toluene	Semi-Volatile		1 mg/l				1 mg/l		17.5 mg/l (1)		14.3 mg/l	424 mg/l	
Toxaphene	Semi-Volatile		3 ug/l						0.73 ug/l	0.2 ng/l	0.71 ng/l	0.73 ng/l	
Vinyl Chloride	Semi-Volatile	2 ug/l					0 ug/l				2 ug/l**	525 ug/l**	

EXPLANATION OF TABLE

* = secondary maximum contaminant level, therefore TBCs

** = Human health criteria for carcinogens reported for three risk levels. Value presented is the 10-5 risk level.

AWQC = Ambient Water Quality Criteria

CWA = Clean Water Act

SDWA = Safe Drinking Water Act

SS = species specific

THM = total trihalomethanes

(1) criteria not developed; value presented is lowest observed effects level (LOEL)

(2) total trihalomethanes: chloroform, bromoform, bromodichloromethane, dibromochloromethane

(3) hardness dependent criteria

(4) pH dependent criteria (7.8 pH used)

(5) if both strontium-90 and tritium are present, the sum of their annual dose equivalents to bone marrow shall not exceed 4 mrem/yr.

(a) EPA National Primary and Secondary Drinking Water Regulations, 40 CFR 141 and 40 CFR 143 (as of May 1990)

(b) EPA National Primary and Secondary Drinking Water Regulations, 40 CFR Parts 141, 142 and 143, Final Rule, effective July 30, 1992 (56 FR 3526)

(c) EPA, Quality Criteria for Protection of Aquatic Life, 1986

TABLE A-3

POTENTIAL SITE-WIDE CHEMICAL-SPECIFIC ARARS/TBCs
STATE SURFACE WATER QUALITY STANDARDS

		Segment 4 & 5 Stream Classification and Water Quality Standards (b)(7) CDH/WQCC									
		Statewide Standards (a) CDH/WQCC					Stream Segment Tab (8)				
Parameter	Type	Table C		Table D			Table E		Table F		Table 2 Radionuclides
		Tables A,B Carcinogenic/ Noncarcin-	Tables I,II,III (1)	Tables A,B Chronic Value (2)	Tables A,B Acute Value (2)	Tables A,B Chronic Value (2)	Tables A,B Fish & Water Ingestion Standards (3)	Tables A,B Radio-nuclide Standards (4)	Tables A,B Acute Value (5)	Tables A,B Chronic Value (6)	
Disolved Oxygen	Field Parameter										
pH	Field Parameter										
Specific Conductance	Field Parameter										
Temperature	Field Parameter										
Total Dissolved Solids	Indicator										
Bicarbonate	Anion										
Carbonate	Anion										
Chloride	Anion										
Fluoride	Anion										
N as Nitrate	Anion										
N as Nitrate+Nitrite	Anion										
N as Nitrite	Anion										
Potassium	Anion										
Sulfate	Anion										
Aluminum	Metal										
Antimony	Metal										
Arsenic	Metal										
Arsenic III	Metal										
Arsenic V	Metal										
Barium	Metal										
Beryllium	Metal										
Cadmium	Metal										
Calcium	Metal										
Chromium	Metal										
Chromium III	Metal										
Chromium VI	Metal										

POTENTIAL SITE-WIDE CHEMICAL-SPECIFIC ARARS/TBCS
STATE SURFACE WATER QUALITY STANDARDS

EG&G/SP/22499/R2TA-3.WK1 07-25-91/LOTUS/WP/22499

TABLE A-3

Segment 4 & 5 Stream Classification and Water Quality Standards (b)(7)										
Statewide Standards (a)					CDH/WQCC					
Parameter	Type	Table C			Tables I, II, III (1)			Stream Segment Tab		
		Tables A, B		Aquatic Life	Acute Value (2)	Chronic Value (2)	Agricultural Standard (3)	Tables A, B (2)	Table C Fish & Water Ingestion Standards	Table D Radionuclides
		Carcinogenic/Noncarcinogenic	Value	Value						
Radium 226+228	Radionuclide									
Strontium 90	Radionuclide								8 pCi/l	
Thorium 230+232	Radionuclide								500 pCi/l	
Tritium	Radionuclide								20,000 pCi/l	
Uranium 233+234	Radionuclide								5 pCi/l	
Uranium 235	Radionuclide								8 pCi/l	
Uranium 238	Radionuclide								60 pCi/l	
Uranium (total)	Radionuclide								20,000 pCi/l	
1,1-Dichloroethane	Volatile				TVS	TVS			40 pCi/l	
1,1-Dichloroethene	Volatile	7 ug/l						7 ug/l		
1,1,1-Trichloroethane	Volatile	200 ug/l						200 ug/l		
1,1,2,2-Tetrachloroethane	Volatile			2.4 mg/l						
1,1,2-Trichloroethane	Volatile	28 ug/l (6)		9.4 mg/l				170 ng/l	170 ng/l	
1,2-Dichloroethane	Volatile	5 ug/l		20 mg/l				28 ug/l (6)	600 ng/l	
1,2-Dichloroethene (cis)	Volatile	70 ug/l						5 ug/l		
1,2-Dichloroethene (trans)	Volatile	70 ug/l						70 ug/l		
1,2-Dichloropropane	Volatile	560 ng/l		5.7 mg/l				70 ug/l		
2-Butanone	Volatile							560 ng/l		
2-Hexanone	Volatile									
4-Methyl-2-pentanone	Volatile									
Acetone	Volatile									
Benzene	Volatile	5 ug/l		5.3 mg/l				5 ug/l		
Benzo(a)anthracene	Volatile									
Benzo(a)pyrene	Volatile									
Benzo(b)fluoranthene	Volatile									
Benzo(g,h,i)perylene	Volatile									
Benzo(k)fluoranthene	Volatile									

POTENTIAL SITE-WIDE CHEMICAL-SPECIFIC ARARS/TBCs STATE SURFACE WATER QUALITY STANDARDS

EG&G/TSP/22499/R2TA-3, WK1 07-25-91/LOTUS/WP/22499

POTENTIAL SITE-WIDE CHEMICAL-SPECIFIC ARARS/TBCs STATE SURFACE WATER QUALITY STANDARDS

[illegible]

TABLE A-3

POTENTIAL SITE-WIDE CHEMICAL-SPECIFIC ARARS/TBCs
STATE SURFACE WATER QUALITY STANDARDS

Segment 4 & 5 Stream Classification and Water Quality Standards (b)(7)												
Statewide Standards (a)												
CDH/WQCC												
Parameter	Type	Table C			Tables I,II,III (1)			Stream Segment Tab		Table 2		
		Aquatic Life			Agricultural			Fish & Water		Radionuclides		
		Tables A,B	Acute Value	Chronic Value	Acute Value	Chronic Value	Standard	Tables A,B	Ingestion	Radio-nuclide	Acute Value	Chronic Value
		Carcinogenic/Noncarcinogenic (2)	(2)	(2)	(2)	(2)	(3)	(2)	(2)	Standards	Value	Value
4-Methylphenol	Semi-Volatile											
4-Nitroaniline	Semi-Volatile											
4-Nitrophenol	Semi-Volatile											
4,6-Dinitro-2-methylphenol	Semi-Volatile											
Acenaphthene	Semi-Volatile	1.7 mg/l	520 ug/l									
Acetone	Semi-Volatile											
Acrylonitrile	Semi-Volatile	7.55 mg/l	2.8 mg/l							58 ng/l	58 ng/l	
Aldrin	Semi-Volatile	2 ng/l	3 ug/l							74 pg/l	74 pg/l	
Anthracene	Semi-Volatile											
Atrazine	Semi-Volatile										3 ug/l	
Benazidone	Semi-Volatile	0.2 ng/l	2.5 mg/l							0.12 ng/l	0.12 ng/l	
Benzoic Acid	Semi-Volatile											
Benzyl Alcohol	Semi-Volatile											
bis(2-Chloroethoxy)methane	Semi-Volatile											
bis(2-Chloroethyl)ether	Semi-Volatile	30 ng/l (6)								30 ng/l (6)	0.0037 ng/l	
bis(2-Chloroisopropyl)ether	Semi-Volatile											
bis(2-Ethylhexyl)phthalate	Semi-Volatile											
Butyl Benzylphthalate	Semi-Volatile											
Carbon Disulfide	Semi-Volatile											
Carbon Tetrachloride	Semi-Volatile	5 ug/l	35.2 mg/l							5 ug/l		
Chlorinated Benzenes	Semi-Volatile											
Chlorinated Ethers	Semi-Volatile											
Chlorinated Naphthalenes	Semi-Volatile											
Chloroalkylethers	Semi-Volatile											
Chlordane	Semi-Volatile	30 ng/l	2.4 ug/l	4.3 ng/l						0.03 ug/l	0.46 ng/l	
Chlorophenol	Semi-Volatile	0.1 ug/l	1.1 ug/l	1.0 ng/l						0.1 ug/l	24 pg/l	
DDT	Semi-Volatile											

POTENTIAL SITE-WIDE CHEMICAL-SPECIFIC ARARS/TBCs STATE SURFACE WATER QUALITY STANDARDS

EG&G/ITSP/22499/R2TA-3.WK1 07-25-91/LOTUS/WP/22499

POTENTIAL SITE-WIDE CHEMICAL-SPECIFIC ARARS/TBCs STATE SURFACE WATER QUALITY STANDARDS

EG&G/TSPI/22499/R2TA-3.WK1 07-25-91/LOTUS/WP/22499

TABLE A-3

**POTENTIAL SITE-WIDE CHEMICAL-SPECIFIC ARARS/TBCs
STATE SURFACE WATER QUALITY STANDARDS**

Segment 4 & 5 Stream Classification and Water Quality Standards (b)(7)											
Statewide Standards (a)						CDH/WQCC					
Table C						Stream Segment Tab					
Aquatic Life						(8)					
Tables I,II,III (1)						Table 2					
Tables A,B						Table D					
Carcinogenic/Noncarcinogenic						Fish & Water					
Acute Value						Radio-nuclide					
Chronic Value						Ingestion					
Value						Standards					
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APPENDIX B
TECHNOLOGY DATA SHEETS FOR
TECHNOLOGIES WHICH PASSED PRELIMINARY SCREENING

APPENDIX B
TECHNOLOGY DATA SHEETS FOR TECHNOLOGIES
WHICH PASSED PRELIMINARY SCREENING

**APPENDIX B.1 TECHNOLOGIES WHICH PASSED PRELIMINARY SCREENING
AND WERE SELECTED FOR TREATABILITY STUDIES**

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Adsorption	B-1.1
Chemical Oxidation of Organics	B-1.4
Ion Exchange	B-1.8
Magnetic Separation	B-1.10
Masonry Cement Stabilization	B-1.23
Oxidation/Reduction	B-1.13
Ozonation	B-1.4
Peroxide Oxidation	B-1.4
Physical Separation	B-1.17
Polymerization Stabilization - Epoxy	B-1.23
Polymerization Stabilization - Polyester	B-1.23
Portland Cement Stabilization	B-1.23
Soil Washing	B-1.20
TRU Clean™	B-1.27
TRU/Clear™	B-1.28
Ultrafiltration/Microfiltration	B-1.30
Ultraviolet Oxidation	B-1.4
Ultraviolet Photolysis	B-1.32

**APPENDIX B.2 TECHNOLOGIES WHICH PASSED PRELIMINARY SCREENING BUT WERE NOT
SELECTED FOR TREATABILITY STUDIES**

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Alkaline Chlorination	B-2.6
AOSTRA TACIUK Process	B-2.7
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Asphalt Based (Thermoplastic) Microencapsulation	B-1.23
Catalytic Dechlorination	B-2.9
Catalytic Oxidation	B-2.11
Electrodialysis	B-2.13
Evaporation	B-2.15
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APPENDIX B
TECHNOLOGY DATA SHEETS FOR TECHNOLOGIES
WHICH PASSED PRELIMINARY SCREENING (Concluded)

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Low Temperature Thermal Treatment	B-2.37
Molten Glass Incinerator	B-2.38
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Oxygen Enhanced Incineration	B-2.45
Powdered Activated Carbon	B-2.47
Precipitation	B-2.49
Radio-Frequency Heating	B-2.51
Reverse Osmosis	B-2.53
Rotary Kiln Incineration	B-2.55
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Steam Stripping	B-2.59
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Thermal Oxidation	B-2.67
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APPENDIX B-1
TECHNOLOGIES WHICH PASSED PRELIMINARY SCREENING
AND WERE SELECTED FOR TREATABILITY STUDIES

ADSORPTION

Description

Adsorption is a term commonly used to refer to both adsorption and absorption. Adsorption is the physical adhesion of molecules or particles to the surface of a solid adsorbent without chemical reaction. Absorption involves the transfer of the molecules or particles from one phase to the other so that they actually become a part of the other phase (medium). Absorption may be physical or chemical in nature.

A number of different adsorption processes exist for treatment of metals and radionuclide contaminants in water. These include activated alumina, a ferrite process, and other processes (U.S. EPA, 1985, 1986a; Schweitzer, 1979).

Activated Alumina: Activated alumina is a porous form of aluminum oxide with a large surface area. It will adsorb liquids, vapors, and gases. For removal of aqueous contaminants, activated alumina is typically used in a column similar to that for ion exchange. It has proven to be successful in the removal of arsenic and fluoride from groundwater (Rubel, 1980; Frankel and Juergens, 1980). Adsorbed species can be removed by flushing the column with a suitable chemical solution, generating a concentrated side stream.

Ferrite Process: This process involves the introduction of ferrite particles into a waste stream. Inorganic contaminants present in the waste stream will sorb to the particles which are then removed by physical separation. The ferrite process also has the capability of being used in a column similar to ion exchange.

Applications

Activated alumina is used to remove small amounts of fluoride and arsenic from potable water and wastewater (Rubel, 1980; Frankel and Juergens, 1980). The fluoride adsorption process is pH dependent with optimal removal occurring at pH 5. Research indicates that selenium can also be removed using activated alumina (Yuan et al., 1983).

Advantages and Disadvantages

Adsorption of metals and radionuclides is a standard technique for removal and concentration of these contaminants. The major disadvantage to adsorption processes is that they produce a concentrated liquid side stream resulting from regeneration. If not regenerated, the sorbent must be disposed as a solid waste.

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CHEMICAL OXIDATION OF ORGANICS

Description

Chemical oxidation is used to degrade hazardous organic materials to less toxic compounds. A number of different chemical oxidation processes exist for treatment of organic contaminants. These include chlorination, ozonation, and treatment by a combination of UV radiation, and ozone, and/or hydrogen peroxide (U. S. EPA, 1985, 1986a; Wentz, 1989).

Chlorination: In this process chlorine is added to water to oxidize both organics and inorganics. Chlorine, which is added in its elemental form (gas), chlorine dioxide gas, or hypochlorite salt, is a strong oxidizing agent in aqueous solutions. The primary use of chlorination has been for disinfection of drinking water. A potential disadvantage of this process is that the chlorine may form potentially toxic chlorinated by-products.

Ozonation: Ozone is a strong chemical oxidant that has been used for purification, disinfection, and odor control of drinking water. Ozone is generated from air or oxygen and is applied by bubbling the gas through the water being treated. Ozone efficiently breaks down some easily oxidizable organics, but has generally been shown to be an ineffective oxidant for halogenated organics at reaction times and concentrations normally used in drinking water treatment. Complete oxidation of organic species to carbon dioxide and water may require high ozone dosage and long contact times. If inorganics, such as iron, are present, their oxidation may inhibit the destruction of organics.

UV/Ozone/Hydrogen Peroxide: The use of ultraviolet (UV) radiation in combination with ozonation has been found to catalyze the oxidation process and is now in common use. This form of treatment is accomplished by contacting the ozone and the contaminated water in a closed reactor in the presence of UV light. The combination of UV and ozone treatment makes it possible to oxidize compounds that would not be oxidized by ozone treatment only. UV radiation causes destruction or weakening of the chemical bonds in the organic compounds, thereby acting as a catalyst for the oxidation process. Hydrogen peroxide can be used in combination with UV light as an alternative to ozone, or all three may be combined.

Complete oxidation of organics results in the formation of carbon dioxide and water. In waste treatment, complete oxidation of all the contaminants is difficult and expensive to achieve, so a variety of low molecular weight organics are formed in the process. Since various degrees of oxidation occur in complex mixtures, it is important that the system be designed for removal of selected target contaminants. A thorough characterization of by-products is necessary.

Applications

Chemical oxidation processes have been reported for dilute waste streams containing aldehyde, mercaptans, phenols, benzidine, unsaturated acids, and some pesticides (Kiang and Metry, 1982).

The UV/Ozone/Peroxide system as marketed by ULTROX International has been used for pilot-scale and full-scale treatment of a variety of organic contaminants (Fletcher, 1987; Barich, 1990). In a pilot-scale test, the system was found to reduce trichloroethylene (TCE) from 200 ug/L to 2.6 ug/L and carbon tetrachloride from 10 ug/L to 2.9 ug/L. The ULTROX system has been used full-scale for treating 200,000 gallons of tetrahydrofuran-contaminated groundwater. The contaminant concentrations were reduced from 5,000 ug/L to nondetectable levels. Groundwater contaminated with TCE, tetrachloroethylene (PCE), and 1,1,1-trichloroethane at 470, 96, and 166 ug/L, respectively, was treated to below drinking water standards in pilot studies. Pilot studies were also conducted and demonstrated the reduction of polychlorinated biphenyl (PCB) concentrations from 50 ug/L to less than 1 ug/L.

Similar systems are manufactured by Solarchem (Ontario, Canada) and Peroxidation Systems, Inc. (Gardenia, California).

Advantages and Disadvantages

Chemical oxidation of organic contaminants has the advantage that the contaminants are destroyed in the process. On a cost basis, UV/ozone/peroxide treatment is competitive with GAC treatment. Natural organics and inorganics may interfere with the oxidation process and increase the oxidant requirements. Undesirable organic by-products may also be formed.

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ION EXCHANGE

Description

Ion exchange can be used for the removal of undesirable anions and cations from a wastewater stream (Eckenfelder 1989). Cations are exchanged for hydrogen or sodium and anions for hydroxyl ions. Most ion-exchange resins used in wastewater treatment are synthetic resins made by the polymerization of organic compounds into a porous three-dimensional structure. Functional ionic groups are usually introduced by reacting the polymeric matrix with a chemical compound containing the desired group. Exchange capacity is determined then by the number of functional groups per unit mass of resin.

Treatment of wastewater by ion exchange involves a sequence of operating steps. The wastewater is passed through the resin until the available exchange sites are filled and the contaminant appears in the effluent. At this point, the process is stopped and the bed is backwashed to remove dirt and to regenerate the resin.

Application

One of the major applications of ion exchange is the removal of chrome from industrial plating streams. Other anions or cations from wastewater streams can be removed. Macroreticular resins are used for the removal of specific organic compounds such as chlorinated pesticides and aromatic hydrocarbons. This technology has been used successfully for the remediation of heavy metals and uranium from wastewater and groundwater at the Hanford (Weiss 1990) and Savannah River Sites (Sferrazza 1990).

Advantages and Disadvantages

One of the advantages of ion exchange is that the removed product from the wastewater stream can be recovered and reused or concentrated for more controlled disposal.

Other ions within a waste stream can compete with the ion of interest to remove in the exchange process thus reducing the capacity. For instance, iron in groundwater competes for the exchange of more hazardous ions like chromium or uranium.

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MAGNETIC SEPARATION

Description

Magnetic separation removes magnetic or recovers nonmagnetic materials. Magnetic separation can be accomplished on either wet or dry wastestreams. There are several types of separators that operate at various intensities, including belt, induced-roll, and drum. The force of the magnetic field is supplied by either electromagnets or permanent magnets. Utilizing a pretreatment can artificially convert nonmagnetic materials to magnetic materials. A V-shaped pole opposite a flat bar is the preferred method for producing a converging field. Drum separators are used for low-intensity magnetic separation. There are three types of drum separators: concurrent, counter-rotation, and counter-current. Concurrent drum separators extract an extremely clean magnetic concentrate from relatively coarse materials. It is often used in heavy medium recovery systems. The counter-rotation type is often utilized in roughing operations because it can handle occasional surges, hold magnetic material losses to a minimum, and can handle high solids loading. The counter-current drum separator is utilized in finishing operations. Typically, it operates on fine materials with particle sizes less than 250 μm . Cross-belt separators are used on dry materials for low-intensity magnetic separation. This separator is used to concentrate moderately magnetic ores. A disc separator is a modified cross-belt separator that provides even greater selectivity.

Induced-roll separators are high-intensity separators. They are primarily used to separate magnetic materials from beach sands, wolframite, tin ores, glass sands, phosphate rock, and iron ores. One specific type of roll separator is the Permroll. Dry separation is utilized on materials with particles greater than 75 μm .

Wet magnetic separators for high-intensity fields include induced roll machines and Jones. One type of induced roll machine is the Gill, which has been effective for separating highly magnetic ilmenite from heavy mineral concentrates. The Jones separator is effective in separating fine hematite ores. Other applications of wet, high-intensity separators include separating magnetic particles from cassiterite concentrates, asbestos, scheelite concentrates, talc, flotation tailings, beach sand, and cyanidation residues.

Another magnetic separation process is Eddy-Current Separation. Eddy currents are currents that are induced in electrically conducting particles when exposed to a changing magnetic field. The interaction between the magnetic field and eddy-currents causes a force to be exerted on a conducting particle. The magnitude of this force is dependent upon the magnetic field, the currents and the motion of the particles relative to the magnetic field. If a mixture of conducting and non-conducting particles are passed over suitable magnetic fields, a different lateral particle deflection will result in the two types of particles being separated. Two eddy-current separators are the Ramp Separator and the Linear Motor.

Applications

This technology will work with any waste containing magnetic particles that can be separated. The process can be used on water, slurries, soils, sludges, and sediments.

Removes particles with diameters as small as 1 micron. Flow rates are 100 times greater than ordinary filtration. When particles get below 0.5 cm, wet methods are utilized instead of dry methods. Eddy currents remove particles in the range of .1 to 4 in.

Advantages and Disadvantages

This process can reduce the volume of soils requiring further processing and/or treatment.

Disadvantages include the need for extensive materials handling and processing. Fugitive dust emissions is also a problem.

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OXIDATION/REDUCTION

Description

The chemical reduction-oxidation (redox) process involves a change of the oxidation state of the reactants; one is increased while that of the other reactant is reduced. Common oxidizing agents include ozone, hypochlorite, and chlorine. Common reducing agents include sodium borohydride, sulfur dioxide, and ferrous sulfamate (U. S. EPA, 1985, 1986a).

The purpose of redox treatment of inorganic compounds (excluding heavy metals) in water is generally to break a compound into simpler, less toxic constituents. Examples are the conversion of sodium cyanide to carbon dioxide and nitrogen using alkaline chlorination and the conversion of ammonium to nitrogen and water using sodium nitrite (Marin et al., 1979).

The use of redox treatment of waste streams containing metals is typically required to enhance a subsequent precipitation step. The redox reaction is used to adjust the metal to an oxidation state that will result in the formation of an insoluble metal salt precipitate that can then be physically removed from the bulk of the aqueous waste stream.

An example is the use of sulfur dioxide to reduce hexavalent chromium to trivalent chromium, which is then precipitated as chromous hydroxide. In general, the use of redox in conjunction with precipitation for the removal of heavy metals is a well established water treatment method.

Applications

A typical redox process for removal of cyanide involves conversion of cyanides to cyanates with a 15 percent solution of sodium hypochlorite at a pH > 10. The cyanates are then further oxidized to N₂ and CO₂ with the sodium hypochlorite solution at pH 8.5. Complete oxidation takes approximately 10 minutes (Marin et al., 1979; EPA, 1980). This type of process is common for treatment of electroplating rinse water.

Reduction of hexavalent chromium to its trivalent state followed by precipitation is a standard process step for treating chromium-bearing aqueous wastes. The solution pH is first adjusted to a pH of 2 to 3 by addition of hydrochloric or sulfuric acid. A reducing agent, typically sulfur dioxide or sodium metabisulfite, is then added. After the reaction is completed, the pH is adjusted to 7.5 to 8.5 using lime or caustic. At this pH, chromium hydroxide has its minimum solubility and precipitates (Lanouette, 1977).

The use of redox reactions for the removal of trace quantities of uranium and transuranic elements from groundwater has not been demonstrated. Processes for recovery and purification of uranium and transuranic elements, however, rely heavily on adjustment of oxidation states. These processes include precipitation as well as acid and solvent extraction. The separation of plutonium from cerium by extraction with tributyl phosphate (TBP) requires that the plutonium be oxidized to the tetravalent state without oxidation of cerium to its tetravalent state. Similarly, the separation of plutonium from uranium requires that the plutonium be trivalent and uranium hexavalent (Benedict et al., 1981). Process solutions typically contain transuranic elements in concentrations orders of magnitude above those required to meet discharge limits.

The oxidation states and solubilities of uranium and transuranic elements at trace concentrations in groundwater have been studied by several researchers in recent years (Nitsche et al., 1988; Kim et al., 1988; Nash et al., 1988; Cleveland et al., 1985). In general, they found Pu(V) and Pu(VI) to be the oxidation states of the soluble plutonium species. Presumably, plutonium solubility could be reduced by reduction to Pu(III) or Pu(IV). The solubility is enhanced by the presence of carbonate and fluoride, which form complexes with the plutonium. Americium solubility is controlled mainly by the formation of radiocolloids.

Advantages and Disadvantages

The use of redox processes has the advantage that often inorganic contaminants may be transformed into less hazardous forms. The ability to adjust oxidation states of metals is advantageous and in some cases necessary for a subsequent treatment process, such as precipitation. A disadvantage of the use of chemical redox reactions is undesirable side reactions. These include the reduction or oxidation of organics and the production of chlorinated organics if the selected process is chlorination (Rice and Gomez-Taylor, 1985). The process will also produce a sludge that requires further treatment or disposal.

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PHYSICAL SEPARATION

Description

Soil contaminants are often found to be associated with particular size fractions of soils, most often the fine particle sizes. Fractionation of the soil based on particle size can, therefore, be an effective means of reducing the volume of the material that requires treatment. The processes effective for performing soil size fractionation include screening, classification, flotation, and gravity concentration (U. S. EPA, 1988b).

Screening: This process is the mechanical separation of materials based on their size. This separation is usually obtained using a uniformly perforated surface. The material is passed over the screen. The larger particles are retained on the surface and the smaller particles pass through. Screening is usually limited to particles larger than 250 μm in diameter (Perry and Chilton, 1973).

Classification: This process is used to separate particles based on their settling rate in a fluid, such as water. A single stage classifier will typically make a single separation, with faster settling materials going out the underflow and the slower going out the overflow. There are three types of classifiers: nonmechanical, mechanical, and hydraulic (Perry and Chilton, 1973).

Flotation: The injection of air into a liquid suspension can cause low-density solids and hydrocarbon solids to float to the surface for removal. This method is used extensively in the mining industry for concentration of minerals. Microbubbles formed by injection of air attach to particles, become trapped under larger particles, or become part of flocs. These particles with the attached air bubbles have a combined specific gravity less than that of water and float to the surface (Ives, 1984).

Gravity Concentration: This technique uses density differences of materials to effect separation. Gravity concentration can be implemented using sluices, shaking tables, and the traditional miner's pan. All of these devices keep the particles slightly apart so that they can move relative to each other and separate into layers of light and dense materials (Burt, 1984).

Applications

Flotation and other physical separation techniques are used to recover copper, uranium, zirconium, and magnetite by the Palabora Mining Company in South Africa (Burt, 1984). The method has also been used for removal of radium from uranium mill tailings in Elliot Lake (Raicevic, 1970). During laboratory testing, flotation was found to reduce radium concentrations from 290 pCi/g to 57 pCi/g.

Several soil decontamination processes in the Netherlands use gravity concentration and flotation for removal of fine particles and organics from extracting agents (Assink, 1985; U. S. EPA, 1988b). Systems similar to this are in the pilot-stage in the United States (Hazardous Waste Consultant, 1989). Pilot plant testing at Rocky Flats in the early 1970s (Garnett et al., 1980) showed that soils contaminated with 45, 284, and 7,515 pCi/g plutonium were reduced to 0.5, 12, and 86 pCi/g, respectively, using physical separation. The cleaned soil fraction ranged from 58 percent to 87 percent of the original volume.

Advantages and Disadvantages

Screening is an inexpensive method for separating particles, but screens are subject to plugging, which can greatly decrease their efficiencies. The use of dry screening generates dust emissions that must be controlled.

Classifiers have high continuous processing capabilities and are very reliable, but soils containing clay or sandy soils containing humus materials can be difficult to process.

Flotation can achieve very high separation rates if the materials are suited to such treatment, but it is a complex and expensive process.

Gravity concentration is a highly efficient and well proven technique, but it has a relatively low process capacity.

Wet processes may produce a liquid waste stream requiring treatment or disposal.

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SOIL WASHING

Description

Soil washing is based on the principle of contaminant removal from soil by washing with a solution. Washing agents can include water, acids, surfactants, solvents, or chelating agents. Contaminated soil is excavated and placed in a reactor for mixing with the extracting solution. Sorbed contaminants are transferred to the liquid phase by dissolving, by forming an emulsion, or by a chemical reaction with the solution. When extraction is complete, the soil particles are physically separated from the solution, and the treated soil can be returned to the excavation. The extractant containing the contaminants requires further treatment for recycling or disposal.

Applications

By selecting the appropriate washing solution, soil washing technology can potentially be used to treat inorganics, metals, organics, or radionuclides in soil. Application of a soil washing reactor system at four sites in the Netherlands demonstrated greater than 80 percent removal efficiencies for polynuclear aromatic hydrocarbons (PNAs), cyanides, heavy metals, mineral oil, and halogenated hydrocarbons (Assink, 1985). Soil structure and chemistry are important variables in applying the technology successfully and require evaluation on a site-by-site basis.

Inorganics that can be washed from soil with water include soluble salts such as carbonates of nickel, zinc, and copper. Dilute solutions of sulfuric, hydrochloric, nitric, phosphoric, and carbonic acid have been widely used in industry to extract metal ions by dissolving basic metal salts including hydroxides, oxides, and carbonates. Heavy metals can be removed from soils by complexing and chelating agents such as citric acid, ethylenediaminetetraacetic acid (EDTA), and diethylenetriaminepentaacetic acid (DTPA) (U. S. EPA, 1985, 1987c). Arsenic and selenium removal can be enhanced with the addition of oxidizers such as hydrogen peroxide (U. S. EPA, 1986a).

Organics that can be removed from soil by water washing include low to medium molecular weight aldehydes, ketones, and aromatics and lower molecular weight hydrocarbons such as trichloroethylene and tetrachloroethylene. Other basic organic groups like amines, ethers, and anilines can be flushed from soil by washing with an acidic solution. Surfactants have been employed to enhance the recovery of petroleum products and PCBs (U. S. EPA, 1985). Removal of organochlorine compounds by extraction with a solvent mixture of toluene, kerosene, and octanol was demonstrated in laboratory experiments on sludges from Rocky Mountain Arsenal (A.D. Little, 1988).

The use of water, inorganic salts, mineral acids, and complexing reagents to extract radionuclides from soils and tailings was reviewed by the EPA (U. S. EPA, 1988b). These extraction techniques have been

applied as bench-scale or pilot-plant testing for removal of radium and thorium but have not been implemented for remediation of a radiologically contaminated site. Water was shown to be ineffective, removing only 10 percent of the radium and virtually none of the thorium from soils tested. Inorganic salt solutions, mineral acids, and complexing reagents all showed high removal percentages in some applications (U. S. EPA, 1988b).

Advantages and Disadvantages

The primary advantage of soil washing is that a variety of types of contaminants can potentially be removed from soils in a reactor under relatively controlled conditions. The process is flexible and can be designed for specific mixtures of contaminants, although treatment of mixtures may require multiple stages using different washing solutions.

Contaminants are not destroyed but are transferred to the aqueous phase. The technology requires a subsequent separation process for liquids and solids and treatment of the resulting solution for recycling or disposal. Soil washing may require the addition of potentially hazardous substances as washing agents. Residual soil washing chemicals remaining in the soil may also be a problem.

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SOLIDIFICATION/STABILIZATION TECHNOLOGIES

Description

Solidification is a process that mechanically binds contaminants to the solidification agents to reduce the contaminant mobility. The process produces a solid matrix of waste with high structural integrity. Stabilization usually involves the addition of a chemical reagent to react with the contaminant producing a less mobile or less toxic compound. Solidification and stabilization are usually used together to immobilize a waste. Two major forms of solidification/stabilization, pozzolanic-based and cement-based, have been used extensively to treat hazardous waste (U. S. EPA, 1985, 1986d). More innovative solidification/stabilization technologies include mixing with organic polymers and asphalt.

Pozzolan-Based: This solidification method uses materials that form a solid mass when mixed with hydrated lime. Pozzolan materials include diatomaceous earth, blast-furnace slag, ground brick, and some fly ashes. After mixing of the waste and pozzolan, hydrated lime is blended into the mixture. The resulting moist mixture is packed into a mold and allowed to cure.

Cement-Based: Cements are often used as binding agents, along with pozzolan materials, to improve the strength and chemical resistance of solidified waste. The types of cement used for solidification can be selected to emphasize a particular cementing reaction. Portland cement has been commonly applied to stabilization of metals. Masonry cement has been tested for stabilization of radionuclides.

Polymer Based: Various organic polymers to produce a stable matrix for stabilizing and solidification of wastes. This method is innovative. Polymer materials which have been applied include epoxies and polyesters.

Asphalt Based: The waste may be stabilized by mixing with bitumen a mixture of high molecular weight asphaltene and malthene hydrocarbons.

Applications

Solidification/stabilization is being used for low-level radioactive and RCRA mixed wastes at the Hanford nuclear reservation (Sferrazza, 1990). After mixing the wastes with portland cement, fly ash, and clay, the cemented wastes are poured into specially constructed near-surface concrete vaults that isolate the cement product from the environment (Collins, 1988). The combination of waste solidification and placement in concrete vaults is designed to contain the waste materials for at least 10,000 years.

Record of Decision (ROD) documents for at least seven Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites have identified solidification/stabilization as the remedial technology of choice for immobilization of heavy metal contaminants. These sites include the Selma Pressure Treating Company, CA; Flowood, MS; York Oil, NY; Chemtronics, NC; Bailey Waste Disposal, TX; Mid-State Disposal Landfill, WI; and Love Canal, NY.

Various solidification/stabilization techniques have been used at DOE sites throughout the United States. The 513 Solidification Unit at Lawrence Livermore National Laboratory uses cement, Envirostone™, Petroset™, and Aquaset™ to solidify liquid wastes. The Los Alamos National Laboratory uses an in-drum solidification technique for immobilization of TRU solid and liquid wastes. Plutonium precipitation sludge is immobilized in-drum at Mound using portland cement. The Oak Ridge Facility uses a fly ash cement to immobilize a treatment pond sludge containing uranium, chromium, nickel, cadmium, and technetium. Portland cement is used to immobilize waste sludge in Rocky Flats pondcrete and saltcrete processes (Sferrazza, 1990).

Advantages and Disadvantages

Solidification/stabilization is a well established process for reducing the mobility and toxicity of hazardous wastes. Solid wastes containing radioactive contaminants are well suited for this process as it contains and reduces the mobility of the radioactive materials. Solidification/stabilization processes increase the volume of the treated wastes. Organic compounds, if present, often interfere with the desired solidification and stabilization process.

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TRU CLEAN™

Description

TRU Clean™ is a proprietary soil washing system that uses a mechanically aquitated gravimetric separator to reduce the volume of actinide-contaminated soils by concentrating the contaminants. A volume reduction of 80% has been achieved on plutonium-contaminated coral sands in a Johnson Atoll pilot plant. Volume reductions of up to 95% are projected after system improvements.

Applications

The process is applicable to soils and sludges contaminated with radionuclides. TRU Clean™ can operate on-site to decontaminate soils, reducing the volume of radioactive waste.

Advantages and Disadvantages

After processing, there is a volume reduction which may result in substantial cost savings in disposing of contaminated soil.

The primary disadvantage is that the process is based on a proprietary soil washing system, which would have to be purchased from a single supplier.

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TRU/CLEAR™

Description

The TRU/Clear™ is a proprietary process being developed by Analytical Development Corporation. The process is used for the removal of trace levels of alpha-emitting transuranic (TRU) elements from water.

The technology is based on ferrate ion (FeO_4^{-2}) chemistry with TRU-removal accomplished by proprietary chemical additives into specific formulations for specific wastewaters. Ferrate chemistry has been studied for many years, but its commercial application has not occurred due to the inability to manufacture significant quantities of the material for large-scale use.

The novel ferrate chemistry which is used by this technology operates via a degradation chemical reaction in which the strongly oxidizing ferrate ion reacts with water to an insoluble hydrated ferric oxide, hydroxide ions, and oxygen gas:



The rate of this reaction is catalyzed by trace metal ions which may be present in solution. In the presence of organic or inorganic reducing agents, the rate of degradation and its stoichiometry can be influenced radically as well. The reaction mechanisms discovered to date during investigation of ferrate chemistry and application indicate a possible violation of equilibrium solubility behavior as it is understood today. The experimental results indicated that transuranic metal elements can be removed using this chemistry to lower concentrations in solution than can be predicated by equilibrium solubility constants which are empirically measured. It is believed that several mechanisms are operating simultaneously in the system which contribute to the overall removal characteristics of the technology, including localized kinetically controlled reactions. These mechanisms are being investigated presently in conjunction with the engineering development of the technology. The total engineering effect of these mechanisms and properties is precipitative removal of transuranic elements from wastewater to unprecedented low concentrations, not predictable by standard analysis.

Application

The process is used for removing uranium and transuranic elements such as plutonium and americium from wastewaters. The process uses conventional precipitation and clarification equipment.

Advantages and Disadvantages

This technology may offer the ability to remove radionuclides to lower levels than achievable with conventional precipitation processes. It is also reported to produce much less sludge than conventional processes.

The primary disadvantage is that the process is based on a proprietary chemical, which would have to be purchased from a single supplier.

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ULTRAFILTRATION/MICROFILTRATION

Description

This process uses special membrane material in equipment very similar to that used for reverse osmosis. The contaminants to be removed may first be chelated to a high molecular weight compound to allow them to be removed by filtration. The membrane material used has a much larger pore size than reverse osmosis membranes. Operating pressures are much lower, typically 50 to 100 psi versus 400 psi for reverse osmosis.

The most recent technology is based on a crossflow element design. In this process, the influent, or feed stream is separated into two effluent streams; the "permeate" or clean stream, and the "concentrate" which retains all of the suspended solids rejected by the membrane. Only the permeate actually passes through the membrane. The feed and concentrate streams flow parallel to the membrane surface, resulting in the term "crossflow." In this type of element, the solids are swept away with the concentrate, eliminating or greatly reducing the potential for the element to plug.

Application

The process is applicable to wastewaters that contain contaminants in particulate form. For example, plutonium is often present as particulates that can be removed by this process. Ionic contaminants may also be removed if they are first complexed to high molecular weight compounds.

Dissolved metals and radionuclides can also be removed by this process if they are first precipitated in a pretreatment process step.

Advantages and Disadvantages

This process offers the advantage of improved removal efficiencies over conventional filtration. The process is easily automated, and pre-engineered package systems are readily available.

The primary disadvantage is relatively higher costs over conventional filtration.

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ULTRAVIOLET PHOTOLYSIS

Description

Ultraviolet (UV) photolysis is a process that destroys or detoxifies hazardous chemicals in aqueous solutions utilizing UV irradiation. Also, photodegradation can be applied to contaminated soil matrices upon proper exposure to the UV source. Adsorption of energy to the UV spectrum results in a molecule's elevation to a higher energy state, thus increasing the ease of bond cleavage and subsequent oxidation of the molecule. Ultraviolet photolysis can either be carried out by an industrial UV light source or solar UV light concentrated onto a reactor.

Application

Ultraviolet photolysis is used on chlorinated aromatic compounds including PCBs and PCDs, organics, and pesticides. UV photolysis is used in wastewater, sludges, and soils.

Advantages and Disadvantages

The major advantage of UV photolysis is the reduction of toxicity and volume of a specific contaminant.

A disadvantage of UV photolysis is that the products of the photochemical reaction can be more hazardous than the original contaminant.

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APPENDIX B.2
TECHNOLOGIES WHICH PASSED PRELIMINARY SCREENING BUT WERE
NOT SELECTED FOR TREATABILITY STUDIES

ACTIVATED CARBON

Description

Granular Activated Carbon (GAC) adsorption is based on the attraction of organic molecules in solution to the surface of the activated carbon. The adsorption process is dependent on the strength of the molecular attraction between the carbon and the organic contaminant, the type and characteristics of the carbon, and the pH and temperature of the solution. Nonpolar organic compounds of low water solubility are most easily adsorbed (U. S. EPA, 1986a).

GAC adsorption is one of the most frequently used techniques for treating aqueous streams contaminated with organics. The carbon is placed in columns that are operated until the effluent concentration reaches unacceptable levels. At this point the carbon has become saturated with the contaminants and must be regenerated for reuse. The carbon is generally regenerated thermally. Pretreatment is typically required for removal of oil, grease, and suspended solids.

Applications

GAC adsorption is an effective process for removing a variety of organics from water. It has been successful for carbon tetrachloride, chloroform, DDT, benzene, acetone, methylene chloride, phenol, trichloroethylene, and xylene among others (U. S. EPA, 1985). In general, GAC can reduce these contaminants from mg/L concentrations to low ug/L concentrations.

The Rocky Mountain Arsenal has used GAC adsorption extensively for treatment of groundwater (PMSO, 1987a, 1987b). Contaminants removed include trichloroethylene, dibromochloropropane, diisopropylmethyl phosphonate, dicyclopentadiene, and various pesticides such as dieldrin and aldrin.

Advantages and Disadvantages

GAC adsorption is a well known and developed technique for removing organic contaminants from water. The adsorbability varies between different classes of organics, but most of them can be removed by this method. The major disadvantage of GAC adsorption is that it requires energy-intensive regeneration or disposal of the carbon, and large amounts of carbon are required for poorly adsorbable compounds, such as chlorinated volatile organics. Residuals include spent carbon and/or waste streams from the regeneration process.

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AIR STRIPPING

Description

Air stripping is a proven technology for removing volatile and semivolatile organic contaminants from water. The process involves transferring liquid phase contaminants to the vapor phase (U. S. EPA, 1986a). This is accomplished by applying liquid to the top of an air stripping column (tower), countercurrent to upflowing air. The tower is filled with packing that provides a large surface area to enable efficient mass transfer between the two phases. Contaminants are stripped from water to air depending on their relative volatility. Strippability is generally evaluated based on the Henry's Law constants of the compounds to be removed. The water concentrations of each compound decrease as they pass through the column. The removal efficiencies can be increased by increasing the height of the packed tower or the number of mass transfer units. Process efficiency is also dependent on the air:water ratio; a higher air:water ratio will improve removal efficiencies.

Since air stripping involves transfer of contaminants to the gas phase, air emission treatment is generally required. Vapor phase activated carbon systems are most commonly used for this purpose, but other alternatives, such as oxidation and incineration, exist. The vapor phase treatment unit may be costly.

Applications

The applicability of air stripping can be determined from the Henry's Law constants of the compounds to be removed. Generally, compounds with Henry's Law constants higher than that for chloroform ($H = 2.9 \times 10^{-3} \text{ atm}^3/\text{mole}$) are considered suitable for air stripping, but less volatile compounds may be removed at high air:water ratios. Low molecular weight halogenated organics are easily removed in this process, while it is somewhat less efficient for removal of semivolatile aromatics such as benzene. Two of the major volatile organic contaminants in Rocky Flats water, trichloroethylene (TCE) and vinyl chloride, have Henry's constants higher than that for chloroform, and the value for tetrachloroethylene is insignificantly different than that for chloroform (Kavanaugh and Trussel, 1980).

Studies by Fang and Khor (1989) show that removal efficiencies as high as 99.8 percent can be achieved by air stripping of volatile organics, such as vinyl chloride, carbon tetrachloride, TCE, 1,1-dichloroethane, toluene, chloroform, benzene, and xylene. High removal efficiencies for removal of these compounds are also reported by the American Water Works Association.¹

¹Occurrence and Removal of Volatile Organics Compounds from Drinking Water. AWWA Research Foundation.

Advantages and Disadvantages

The major advantages of air stripping are ease of operation and high removal efficiencies for volatiles. Disadvantages of this technology are that efficient treatment is limited to volatiles, and transfer of contaminants to the vapor phase generally makes costly emission treatment necessary.

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ALKALINE CHLORINATION

Description

The alkaline chlorination process oxidizes cyanide (CN) by the addition of chlorine. The initial reaction forms cyanogen chloride (CNCl) and is instantaneous at all pH levels (Eckenfelder 1989). One part cyanide requires 2.73 parts of chlorine to form CNCl. With the addition of caustic, sodium cyanate (NaCNO) is formed from CNCl via a pH dependent reaction. NaCNO is then further oxidized with the addition of chlorine to carbon dioxide and nitrogen. Alkaline chlorination can be accomplished in either batch or continuous mode.

Application

The principal use of alkaline chlorination is for the treatment of wastewater streams containing free and complex cyanides. Process streams from mining and manufacturing indicate most usage of this technology.

Advantages and Disadvantages

The primary advantage of alkaline chlorination is that it is a proven technology which can be applied to ground and surface water matrices.

The disadvantage of alkaline chlorination is that the reaction is slowed down or inhibited when there is a presence of organic and oxidizable metals.

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AOSTRA TACIUK PROCESS

Description

The AOSTRA Taciuk process is a thermal technology for removal of volatile organics from solids and sludges. The AOSTRA Taciuk unit consists of a compartmentalized, horizontal, rotating drum where volatilization of organics, pyrolysis of residuals, oxidation of coked organics and heat recovery are sequentially performed in successive chambers of the unit. Soil fed to the unit is warmed in the first chamber, where volatiles are evolved. Vapors from this step are recovered and condensed. The resulting condensate consists of organic and water phases which are separated. The soil then moves into the higher temperature pyrolysis zone, where organics are vaporized and thermally cracked. Vapors from this step are recovered and condensed. Soil treated in this step is coated with coke. The coked soil moves into the oxidation zone, where the coke is burned off. The soil then moves to the heat recovery zone, where heat from the treated soils is used to heat incoming soils. Off gas for treatment consists of combustion air used to heat the unit and flue gas from the soil oxidation step.

Applications

The process is applicable to soils and sludges contaminated with organic compounds. Most of the organics are vaporized or pyrolyzed and recovered for disposal. Organics which are not volatile enough to be driven off in the first step are pyrolyzed (thermally decomposed without oxygen). It is probable that gaseous pyrolysis products will be more toxic than the original organic contaminants. The degree of decontamination achieved by the process will depend on the volatility of the organics in the soil.

Advantages and Disadvantages

The main advantage of the AOSTRA Taciuk process is its lower operating costs. The process uses fuel only to heat the soils and volatilize and pyrolyze organics. The organic contaminants are not destroyed; no excess air is used for incineration of the organics. Off gas cleanup costs and fuel consumption are lower for the AOSTRA Taciuk process than for typical incineration technologies. The technology was originally developed for enhanced oil recovery from tar sands and is considered proven and commercially available.

The process produces organic residuals which will require treatment and/or disposal. Since the recovered organic residuals will be partially products of pyrolysis, it is probable that some constituents of the recovered organics will be more toxic than the constituents originally in the waste. Applicability of the process to a particular site will require treatability testing.

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CATALYTIC DECHLORINATION

Description

Catalytic dechlorination uses hydrogen gas to react with halogenated organic compounds at high pressure. Catalysts are used to promote the reaction. The process produces off gas and a liquid effluent. The off gas contains hydrogen and hydrogen chloride gas and requires treatment prior to release. The liquid contains partially dechlorinated hydrocarbons and hydrochloric acid and also requires treatment.

Applications

The process is applicable to polychlorinated organic compounds in liquids and gases. The waste feed may require pretreatment to remove sulfur and other constituents which may poison the catalysts. Catalytic dechlorination achieves partial destruction of chlorinated compounds. The process is applicable to conditions which require reduction of toxicity of the waste stream. The highest demonstrated removal efficiency is 94 percent.

Catalytic dechlorination is not applicable to volatile organics, metals or radionuclides. Metals and inorganics interfere with the process and must be removed before treatment.

Advantages and Disadvantages

The primary advantage of the process is its applicability to polychlorinated organics. Catalytic dechlorination is useful for reducing the toxicity of compounds such as PCBs, dioxins and polychlorinated benzenes.

The process does not achieve a high degree of destruction efficiency. It has been demonstrated at the bench scale and in a prototype commercial reactor, but no commercial operating experience exists. Catalytic dechlorination is applicable to a limited number of polychlorinated compounds. Effluent from the process probably would require further treatment. It is expected that some catalysts used in the process may be toxic. Costs for implementing the process are unknown.

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CATALYTIC OXIDATION

Description

Catalytic oxidation is used to destroy organic compounds in a gaseous medium. The catalyst lowers the activation energy of the oxidation reaction so that combustion of organic constituents occurs at lower temperatures. The lower operating temperature results in lower fuel consumption than for other incineration technologies. Heat released by oxidation of the organic constituents can be recovered to preheat gases entering the catalyst bed. If the heat released by the oxidation reaction is not sufficient to maintain the catalyst bed temperature, supplemental energy, in the form of resistance heat or additional organics in the gas stream, is required.

Applications

Catalytic oxidation is applicable to a wide range of organic constituents in gaseous media. Most catalysts are poisoned (deactivated) by sulfur or halogens in the gas stream. However, catalysts which can be used for chlorinated hydrocarbons have been developed recently. Catalysts have an upper limit to their operating temperature above which damage to the catalyst occurs. Since the heat of combustion raises the temperature of the catalyst bed, the rate of heat release must be controlled to avoid damage to the catalyst. This is commonly done by controlling the concentration of organic contaminant in the incoming gas stream.

The process is not applicable to metals or radionuclides. Some gaseous inorganics poison some catalysts. The system is not applicable to gas streams with significant heat value (thermal incineration or condensation of organics would be better). Catalytic oxidation is not applicable to gas streams containing particulates.

Advantages and Disadvantages

The primary advantages of catalytic oxidation are its low operating cost and applicability to a variety of organic constituents. The technology is well developed and commercially available. Catalytic oxidation can be used in combination with technologies which produce an off gas containing organics.

Catalysts are sensitive to temperature and gas composition. The catalytic oxidation process can be difficult to control if the gas composition is variable. Relative humidity of the gas stream has a large effect on some catalysts. Off gases containing halogens or sulfur probably will require treatment for control of acid gases. It would be relatively difficult to bench test an actual gas sample under conditions similar to those in the field.

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ELECTRODIALYSIS

Description

Electrodialysis is a membrane separation process that can be used to remove ionic species from a water stream. A typical electrodialysis cell consists of an anode and a cathode separated by an anion permeable membrane near the anode and a cation permeable membrane adjacent to the cathode. An electrical current is applied across the cell. As the water flows through the channel between the two membranes, the positively charged ions are drawn through the cation permeable membrane to the cathode. Likewise, the negatively charged ions are drawn to the anode. As a result there is a significant reduction in ionic species concentration in the intermediate channel containing the treated effluent (Weber, 1972). An electrodialysis system generally consists of many thin cells stacked in parallel. The resultant waste side stream of anion and cation concentrated water requires further treatment or disposal. Periodic cleaning of the system can be performed by reversing the electrolytic potential across the cells.

Applications

Electrodialysis can be applied as a treatment method to contaminants including metals and inorganics that are charged species in water. Electrodialysis has been extensively used on a commercial scale for desalination of water (Buros, 1989). Treatment of metal-bearing hazardous waste streams, such as plating wastes, is another typical application for electrodialysis (Grosse, 1986).

Advantages and Disadvantages

Electrodialysis is an effective method for concentrating some charged species from a waste stream into a reduced volume of wastewater. Compared to reverse osmosis, the membranes used in electrodialysis are more tolerant of the chemical environments of waste streams and are easier to clean (Buros, 1989; Grosse, 1986).

Contaminants are not destroyed by electrodialysis, but are concentrated into a lower volume waste stream that requires treatment and disposal. Pretreatment of some influent streams may be required to prevent membrane fouling.

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EVAPORATION

Description

Evaporation is used to remove a volatile liquid from a non-volatile liquid or dissolved solid. Evaporation involves the addition of heat and/or application of a vacuum to volatilize the liquid. The evaporated liquid is condensed (usually the heat of condensation is recovered to preheat incoming liquid) and recovered for reuse or disposal. The non-volatile constituent becomes concentrated in a solution of residual liquid. In some applications, the waste may be evaporated to the extent that solids precipitate.

Applications

Evaporation is used to decrease the volume of a waste to be treated and/or disposed. Evaporation does not treat the hazardous constituents. Evaporation is applicable to volatile liquids containing (relatively) non-volatile solutes, where the solvent and solute are stable at the evaporation temperature. Organics, inorganics, metals and radionuclides may be treated by this process. The concentrate produced will require further treatment in most cases.

Evaporation is not suitable for application to cases in which the solvent and solute(s) have similar volatilities.

Advantages and Disadvantages

The primary advantage of evaporation is that it reduces the volume of waste requiring treatment, thus lowering treatment costs. Evaporation is well known, mature technology, available from a large number of vendors. It is applicable to a variety of conditions.

The main disadvantage of evaporation is that it has relatively high operating costs. Evaporation concentrates hazardous constituents in a brine requiring further treatment.

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FLUIDIZED BED INCINERATION

Description

Fluidized bed incineration uses air blown upward through the combustion zone of the incinerator to fluidize a bed of sand, or other granular media. The result is a highly turbulent combustion zone with a large heat capacity. Waste material, including solids, liquids, sludges or gases, is injected directly into the fluidized bed. Volatiles are driven out of the waste and oxidized. Inerts accumulate in the fluidized bed. Bed material is occasionally drained from the fluidized bed to maintain an acceptable pressure drop across the bed. The operating temperature of the fluidized bed is limited by the softening point of the inerts in the feed material. If the operating temperature exceeds the softening point, agglomeration of bed media into particles too large to fluidize may occur. Combustion efficiency suffers when bed agglomeration occurs to an appreciable degree.

Applications

Fluidized bed incineration may be applied to organics and some inorganics in water, sludges, solids or gases. Treatment of off gases for control of emissions is required. Wastes containing metals may require treatment of drained bed media to immobilize the metals.

The process is not applicable to wastes with low softening points. Fluidized bed incineration has a neutral effect on metals and non-volatile radionuclides, though the technology has been used for volume reduction of low level radwastes composed primarily of combustible material (such as paper or graphite). The technology is not applicable to materials containing volatile or semivolatile metals.

Advantages and Disadvantages

Fluidized bed incineration is applicable to a wide variety of organic constituents. It is a well understood, commercially available technology. The high degree of turbulence in fluidized bed incinerators allows them to achieve the same degree of combustion efficiency with lower operating temperatures. Because of this, fluidized beds frequently have lower operating costs than other incinerators under similar conditions.

The technology has a neutral effect on most inorganics. It is not applicable to volatile or semivolatile metals nor to wastes with low softening points. Operating costs are moderately high because of the power required to fluidize the bed media. Wastes with little or no heating value require addition of supplemental fuel. Pilot testing is readily accomplished through a number of vendors, but bench testing is uncommon and of questionable value.

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FREEZE CRYSTALLIZATION

Description

Freeze crystallization is a general separations process used to remove pure components from solutions by crystallizing the materials to be removed. This process has been used for applications as diverse as organic chemical refining and fruit juice concentration, and is also suited for treating hazardous wastes.

The basic operation involved is the production of crystals by removing heat from a solution. Crystals produced in this manner invariably have very high purities. Once small, uniform crystals have been produced, they must be washed to remove adhering brine. The brine is recycled to the crystallizer, so that as much solvent as desired can be recovered. The pure crystals are usually melted in a heat-pump cycle, which further improves the energy efficiency of the process.

When one or more of the solutes exceeds its solubility, additional crystal forms are produced, but they are formed separately from each other and from the solvent crystals. Since in most waste applications the solvent is water, and ice is always less dense than the solution and the solutes usually more dense, it is easy to separate these crystals by gravity.

Applications

The process works on aqueous streams containing heavy metals, all types of dissolved organics, and radioactive materials. This technology can also be used to process the liquid stream from soil washing operations.

The process is economically and technically competitive on very contaminated streams. For example, wastes with heavy metals require concentration of 1,000 to 10,000 mg/l to be economically recoverable with freezing.

Advantages and Disadvantages

Freeze crystallization has several advantages for remediation and waste recovery applications. First, it is a very efficient volume reduction process, producing a concentrate that has no additional chemicals added to it - if disposal in a hazardous waste landfill, or incinerator destruction is required, this will reduce these costs substantially. When a large fraction of the solvent (usually water) is removed from a waste, the remaining impurities often begin to crystallize as well - they are often sufficiently pure to have by-product value for resale.

The main disadvantage of this process is its relatively high cost for treating streams with low concentrations of contaminants. The process is also relatively complex, requiring numerous pieces of equipment, compressors, heat exchangers, and pumps.

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GAMMA IRRADIATION

Description

This technology uses ionizing gamma radiation to decompose organic compounds. The media containing the organic constituents is exposed to a source of gamma radiation. The radiation excites the organic constituents to a higher energy state, which causes them to decompose. Gamma irradiation has been successfully applied to disinfection of sewage sludge. The process has been demonstrated to be effective for destruction of chlorinated hydrocarbons.

Applications

Gamma irradiation is applicable to disinfection of sewage sludge and destruction of organic constituents, particularly chlorinated hydrocarbons. Exposure of organic compounds to gamma radiation produces partially decomposed organic compounds as well as hydrogen, oxygen and chlorine. Treatment of off gases produced by the technology would be required. It is possible that some of the partially decomposed organics may be more toxic than the original constituents.

Some organics are not amenable to treatment by gamma irradiation. Treatability testing would be required prior to application of the technology in the field. The process has no reported effect on heavy metals or radionuclides.

Advantages and Disadvantages

Gamma irradiation is a proven technology for disinfection of sewage sludge. The process has also been demonstrated to be effective for destruction of some organic constituents, particularly chlorinated hydrocarbons. The process seems well suited for application to sewage sludge contaminated with halogenated organics. The process may also be used for treatment of water or sludges contaminated with halogenated organics and which may foster unwanted biological activity. It is expected that bench testing should be available for this technology. The results of bench testing will probably be representative of the effectiveness of the process.

The process appears limited in the scope of its applicability. The gamma irradiation process produces off gas which will require treatment. It is not clear what destruction efficiencies are achievable or what the costs of the process are.

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GLASSIFICATION/VITRIFICATION AND IN-SITU VITRIFICATION

Description

Vitrification of wastes involves combining the wastes with molten glass at a temperature of 1,350°C or greater. However, the encapsulation might be done at temperatures significantly below 1,350°C (a simple glass polymer such as boric acid can be poured at 850°C). This melt is then cooled into a stable, noncrystalline solid (U. S. EPA, 1985).

One variation on this process is in-situ vitrification (ISV) in which wastes and soils or sludges are melted in place to bind the waste in a glassy, solid matrix resistant to leaching. In the ISV process, four electrodes are inserted into the soil to the desired depth. A glass frit is placed between the electrodes to act as a starter path for the initial melt to form. As the melt grows downward and outward, it incorporates nonvolatile elements and destroys organic components by pyrolysis. The pyrolyzed by-products migrate to the surface of the melted zone where they combust in the presence of oxygen. Inorganic materials are dissolved into or are encapsulated in the melt. Convective currents within the melt uniformly mix materials that are present in the soil. When the electric current ceases, the molten volume cools and solidifies into a vitrified mass. A hood placed over the processing area provides confinement for the combustion gases, drawing the gases into an off-gas treatment system.

Applications

Vitrification is best used for soils with a high concentration of contaminants or with contaminants that must be completely immobilized (such as radioactive species). To be considered for vitrification, the wastes should be either stable or totally destroyed at the process temperature (U. S. EPA, 1985).

In-situ vitrification will work with fully saturated soils; however, the water in the soil must be evaporated before the soil will begin to melt. Soils with permeabilities greater than 10^{-4} cm/sec are difficult to vitrify in the presence of flowing groundwater and, therefore, some type of groundwater diversion may be necessary. If buried metals, such as drums, occupy over 90 percent of the linear distance between electrodes, a conduction path that leads to electrical shorting between electrodes may result.

Several vitrification facilities for treatment of radioactive wastes are currently under development. The Hanford Waste Vitrification Plant is designed to fuse high-level radioactive mixed wastes into a glass product. The facility is expected to be completed by mid-1991. The Defense Waste Processing Facility will use vitrification for the immobilization of high-level waste from the Savannah River Site. This facility is almost complete, with cold testing scheduled for September 1990 and hot start-up planned for January 1992. The West Valley Nuclear Services Co. has constructed a vitrification system as part of the West Valley Demonstration Project. The vitrification system has completed a 5-year period of testing

using simulated wastes and is currently being renovated. West Valley is preparing a Part A Radioactive Mixed Hazardous Waste permit for the facility (Sferrazza, 1990).

The Idaho National Engineering Laboratory is evaluating the feasibility of using in-situ vitrification for treatment of buried wastes at this facility. The process has undergone laboratory and engineering scale tests at the Pacific Northwest Laboratory, where the equipment was developed, and has been applied once at the Idaho National Engineering Laboratory on a small test area. Starting in 1992, three larger scale tests are planned (Sferrazza, 1990).

Advantages and Disadvantages

The primary advantage of vitrification is that it effectively immobilizes nonvolatile species in a solid that is very durable and resistant to leaching. Disadvantages of this technology are related to its high cost, which is the result of the large amount of power that is required to melt the glass or soil and the need for specialized equipment and trained personnel (U. S. EPA, 1985). The presence of high moisture content or high organics may also hinder operation. Significant concentrations of combustible gases may also produce a safety hazard. This process may need an offgas collection and treatment system for volatile and semivolatile organics and volatile metals.

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INFRARED ELECTRIC FURNACE

Description

The infrared electric furnace uses infrared radiation (IR, or heat) to volatilize organic constituents in a waste feed. The off gas from the process is then treated by an afterburner and particulate and acid gas scrubbers. Different types of infrared electric furnaces are available. The type which has been most thoroughly demonstrated uses a moving woven wire belt to move the waste through a furnace. The furnace is heated by electric elements which generate radiant heat. The waste is spread on the belt in a layer approximately one inch thick. Objects fed to the infrared electric furnace should be less than two inches in diameter. Some waste materials will require pretreatment to be acceptable for feeding to the furnace. In most applications, no combustion takes place in the furnace. Organics are volatilized, and possibly pyrolyzed, in the furnace and oxidized in the afterburner.

Applications

The infrared electric furnace is applicable to organic constituents in sludges and solids. Wastes containing large objects will require feed preparation prior to treatment in the infrared electric furnace. Because little excess air is used in the furnace, energy requirements of the infrared electric furnace are lower than for other thermal treatment technologies. Wastes containing metals may require treatment of solid residuals to immobilize the metals.

The process has a neutral effect on metals and radionuclides. The technology is not applicable to materials containing volatile metals.

Advantages and Disadvantages

The infrared electric furnace is applicable to a wide variety of organic constituents. It is a developed, commercially available technology. The technology has relatively low operating costs compared with other thermal technologies, because it has lower fuel consumption due to the smaller volume of off gas generated. Off gas cleanup costs are less in some cases because particulate carried out of the furnace is lower than other thermal technologies. The infrared electric furnace may be better suited for treatment of wastes containing semi-volatile metals than other thermal methods because it operates at a lower temperature. It is likely that the infrared electric furnace may be successfully bench tested.

The technology has a neutral effect on most inorganics. It is not applicable to volatile metals. The technology may not be effective for some non-volatile or semi-volatile organics.

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IN-SITU BIOREMEDIATION OF GROUNDWATER

Description

In-situ aerobic biological treatment of groundwater involves the stimulation of biological growth in the contaminated zone in order to reduce the contaminant concentrations. Microorganisms that can use some or all of the contaminants as substrate will normally exist in a contaminated environment. The microorganisms are stimulated to increase their biological growth and consumption of contaminants through addition of an oxygen source and essential nutrients and micronutrients. Anaerobic processes also exist.

The aerobic in-situ treatment system generally consists of injection wells for injecting an oxygen source and required nutrients and extraction wells for monitoring and recovering by-products. The most common oxygen source is dilute hydrogen peroxide. Inocula of acclimatized bacteria may be added as needed. The treatment efficiency is measured in terms of contaminant reduction, dissolved oxygen, and bacterial growth.

In-situ treatment may also be carried out as an anaerobic process. This requires that anaerobic conditions are established in the contaminated zone. The operation of such a system is essentially the same as for the aerobic, except that no oxygen addition is involved. The anaerobic and aerobic in-situ processes may also be combined and operated in series.

Applications

In-situ biodegradation has been used for various applications such as gasoline spills and wood-treating wastes containing semivolatile and nonvolatile organics (U. S. EPA, 1986c, Litchfield, 1986). While it was previously thought that trichloroethylene (TCE) was only anaerobically degradable, recent in-situ studies have demonstrated that TCE can also be treated aerobically in-situ (Roberts et al., 1989).

Even though most compounds can be biologically degraded, it should be noted that in-situ treatment is dependent on other process-controlling factors such as geological and hydrological conditions.

Advantages and Disadvantages

The major advantages of in-situ biological treatment are:

- Can be carried out in place
- No sidestreams generated
- Only environmentally safe compounds are added

- Relatively inexpensive operation.

Disadvantages include:

- Level of cleanup generally less than for aboveground treatment trains
- May be difficult to control
- Difficult to treat broad mixtures of compounds.

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IN-SITU BIOREMEDIATION OF SOILS

Description

In-situ biological treatment of soils involves stimulating existing or introduced soil microorganisms that will use organic contaminants in the soil as a substrate for growth. Both aerobic and anaerobic degradation of contaminants is possible in-situ depending on the availability of oxygen. In both cases, stimulation of biological growth and consumption of contaminants is typically achieved by the addition of essential nutrients such as ammonia and phosphate. Depending on the depth of soils to be treated, nutrient solutions can be added by sprinkling and subsequent infiltration or by a system of injection wells. Stimulation of aerobic degradation also requires the addition of an oxygen source such as hydrogen peroxide for the soil microorganisms. Extraction wells are typically installed for monitoring and recovery of by-products (U. S. EPA, 1985, 1986c).

Applications

In-situ biological treatment is particularly useful where soil excavation is difficult or extremely expensive. The method has usually been applied as part of a combined in-situ treatment of organics in soils and groundwater at a site. Soil and groundwater contamination from spills of gasoline and other petroleum products has been successfully treated by in-situ bioreclamation to where aquifer contamination from the site was below drinking water standards or was nondetectable (U. S. EPA, 1985). An in-situ biological treatment system at Kelly Air Force Base demonstrated significant degradation of aliphatic hydrocarbons and chlorinated aromatics in soils and groundwater (Wetzel et al., 1986). These applications used aerobic degradation; anaerobic biodegradation for in-situ applications is more difficult because of problems in maintaining an oxygen-free environment and because of temperature sensitivity of the microbes. Even though most organic compounds can be biologically degraded, it is important to note that the applicability of in-situ biological treatment is very dependent on geologic and hydrologic conditions at the site.

Advantages and Disadvantages

In-situ biological treatment of soils can be carried out in place and is, therefore, relatively inexpensive. Only environmentally safe compounds are added in the treatment, and no side streams are generated. The in-situ process may be difficult to control and the level of cleanup is generally lower than for more controlled aboveground treatment trains. Treatment of a broad mixture of contaminants can also be problematical.

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IN-SITU STABILIZATION

Description

Solidification is a process that produces a monolithic block of waste with high structural integrity. The contaminants do not interact chemically with the solidification agents but are mechanically bonded. Stabilization involves the addition of reagents which limit the solubility or mobility of the waste constituents. Solidification and stabilization techniques are often used together.

The in-situ process is done by injecting the stabilization and solidification agents directly into the soil. Specially designed equipment is available for this purpose.

Application

Potential applications include in-situ remediation of soils containing metals and radionuclides. The process has also been considered for hydrocarbon contamination. The process is particularly applicable to highly porous and permeable matrices.

Advantages and Disadvantages

This technology is potentially more economical than similar process that are based on excavation and above-ground treatment. Potential problems due to fugitive dust emissions are eliminated.

While the process may work initially, its long-term effectiveness is unknown. Using this process is very site-specific, and local site conditions must be well defined. Monitoring and control of the process may also be very difficult.

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LAND TREATMENT

Description

Land treatment involves application of waste onto soil in order to stimulate biodegradation of organic matter and hazardous constituents in the waste. Land treatment is both a treatment method and a disposal method. As such, consideration must be given to the Land Disposal Restrictions of Title 40 of the Code of Federal Regulations, Part 268 (Land Ban). Constituents restricted from land disposal under Land Ban may not be treated by this method.

Applications

Land treatment can be used for treatment of organic constituents which are amenable to biodegradation. However, Land Ban prohibits land disposal of hazardous wastes unless the wastes meet the treatment standards published in 40 CFR 268. Organic constituents not restricted from land disposal under Land Ban may be treated.

Land treatment is not applicable to organic constituents which are not amenable to biodegradation. Examples include PCBs, dioxins and certain pesticides. Land treatment has no effect on metals or radionuclides.

Advantages and Disadvantages

The primary advantage of land treatment is its low cost for implementation compared to other bioremediation methods and to incineration methods.

Land treatment is very limited in its applicability by Land Ban regulations. The effectiveness of the treatment method must be tested prior to field application. Bench test results are expected to be of limited value.

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LOW TEMPERATURE THERMAL TREATMENT

Description

Low temperature thermal desorption is a non-combustion process in which organic contaminants and water are volatilized and removed from contaminated soils, sludges, and sediments. A proprietary process called X-Trax uses an inert nitrogen carrying gas to prevent combustion. The mobile system includes an externally fired dryer trailer and a gas treatment trailer that includes a high energy scrubber, two heat exchangers and a series of carbon absorbers. Condensed vapors are stored in tanks, awaiting further treatment.

Applications

The process is applicable to soils and sludges contaminated with organic compounds. Most of the organics are vaporized.

The technology is not applicable to metals, radionuclides and some semi-volatile organics.

Advantages and Disadvantages

Raising the soil to temperatures at which the contaminants present undergo decomposition is an effective means of contaminant removal. The low temperature thermal treatment system decrease energy requirements and simultaneously reduce downstream pollution abatement equipment and operations costs. Further treatment of the condensed vapors is a disadvantage.

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MOLTEN GLASS INCINERATOR

Description

Molten glass incineration uses heat generated from a bath of molten glass to oxidize organic constituents and to incorporate inorganics in a vitrified glass matrix. The glass melt may be heated by several methods, including overfiring with fuel burners and Joule heating. (Joule heating uses the heat produced by electrical resistance when electric current is passed through molten glass.) Air is injected in the combustion zone over the melt to induce turbulence and to supply oxygen for the combustion process. Ash falls into the melt and is vitrified. Glass forming materials may be added to the feed to modify the glass characteristics such as physical strength and metal ion mobility. Glass, containing metals and inorganics, is drawn off periodically and cast into shapes for disposal. Off gases from the combustion process must be treated to control emissions of acid gases and particulates.

Applications

Molten glass incineration is applicable to mixed waste streams containing organics, inorganics, metals and radionuclides. The technology is applicable to a variety of waste matrices, including liquids, sludges and slurries, soils and bulk solids. Molten glass incineration is particularly well suited to treatment of metallic radionuclides, since they are vitrified and immobilized in the glass matrix. However, the long term disposition of gaseous daughter products produced by radioactive decay (such as radon) is unknown. The technology may not be well suited for treatment of wastes containing a volatile or semivolatile metals (such as mercury).

The overall degree of volume reduction achieved by molten glass incineration depends on the nature of solids in the waste feed. Wastes containing large amounts of ionic material do not form glass with good properties. Such applications will require addition of glass forming material (such as silica sand) in order to form an acceptable glass. If the amount of glass formers required is large, it is possible that little or no volume reduction, or even a volume increase, may be accomplished.

The technology may require a large degree of off gas treatment if used to treat wastes with high concentrations of bound nitrogen.

Advantages and Disadvantages

The primary advantage of molten glass incineration is its applicability to a wide variety of components and waste matrices. It is commercially available and bench tests may be performed.

As with most incineration technologies, molten glass incineration requires off gas treatment in most cases. In addition, operating costs for molten glass incineration can be high for some wastes, because of refractory corrosion. Energy consumption is moderate for Joule heated units; higher for overfired units.

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MOLTEN SALT/SODIUM FLUXING

Description

Sludges or shredded solids are fed to a molten salt bath consisting of sodium carbonate or a mixture of sodium and potassium salts. The bath is agitated with air to promote mixing and prevent evolution of bulk gases. Organic constituents in the waste are oxidized to carbon dioxide and water. Halogens evolved by oxidation of constituents in the waste are captured in the salt bath, as are metals. The need for extensive off gas treatment is reduced in this manner. Inorganics and inerts are captured in the salt bath. The process produces a salt solution containing metals, if any are present in the waste.

Applications

The process is applicable to a variety of organic constituents in solids and sludges. It is particularly well suited to halogenated organics, since the halogens are captured in the salt bath.

The molten salt/sodium fluxing process is not well suited to use on aqueous wastes due to their tendency to flash into steam. It is likely that treatment efficiency would be low for such wastes.

Metals and inerts are captured in the salt bath, but mobility of metals and radionuclides is not affected by this technology. The salt bath may require additional treatment to reduce metal mobility. Molten salt/sodium fluxing is not applicable to volatile or semi-volatile metals.

Advantages and Disadvantages

The primary advantages of this process are its applicability to a variety of organics and the reduced requirement for off gas treatment. Halogens in the waste are captured in the salt bath, reducing the need for acid gas scrubbing. It is expected that bench testing of wastes can be performed by the equipment vendor.

The process has been demonstrated on the pilot scale and is available for application on a commercial scale. However, it is not proven on a commercial scale. Operating costs are unknown.

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MULTIPLE CHAMBER INCINERATION

Description

A multiple chamber incinerator is a solid waste furnace which consists of several chambers separated by curtain walls. Flue gases moving through the incinerator must make several abrupt changes of direction prior to exiting the incinerator. Each change of direction tends to disentrain particulate from the flue gas. Waste is charged into the primary chamber, where it stays during the combustion process. If the waste does not contain enough heating value, auxiliary fuel is added in the primary chamber. Auxiliary fuel is usually added to the secondary chamber regardless of the heating value of the waste. Multiple chamber incinerators tend to be operated in batch mode, however it is possible to fit in-line types with automatic ash removal devices and moving grates to allow continuous operation. Multiple chamber incinerators are designed to treat solid waste (versus hazardous waste) and to operate without air pollution control.

Applications

Multiple chamber incinerators are designed for incineration of solid wastes. The technology is applicable to organics in solids. Such devices are not strictly applicable to destruction of hazardous constituents. Multiple chamber incineration is used to reduce the volume of solids containing organic material. As a result of the volume reduction, metals will tend to be concentrated in the solid residue (ash). The ash may require further treatment to reduce metal ion mobility. It may be necessary to design and install an off gas treatment system in order to apply multiple chamber incineration. Destruction and removal efficiencies have not been measured for hazardous constituents in multiple chamber incinerators.

Multiple chamber incineration is not applicable to incineration of liquids or gases. The technology is not applicable to volatile or semi-volatile metals. It has no effect on other metals or radionuclides.

Advantages and Disadvantages

The primary advantage of multiple chamber incineration is that it is well known, commercially available technology. It has relatively low capital costs. The technology may be bench tested.

The main disadvantage of multiple chamber incineration is that it is not applicable to destruction of hazardous wastes. The technology has relatively high operating costs because of the large amount of excess air treated. The process will probably require application of off gas treatment. Ash treatment will probably be required for solids containing heavy metals or radionuclides.

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NEUTRALIZATION

Description

Neutralization is basically a pH adjustment process intended to achieve an acceptable pH level in an aqueous waste prior to discharge. Alkaline chemicals, i.e., sodium hydroxide or lime, are added to low pH streams. Acids, typically sulfuric acid, are added to high pH streams.

Application

This process is generally used with other processes as a pre- or post-treatment step. It is also used alone if the original wastewater is either too acidic or too basic.

Advantages and Disadvantages

The process is easily automated using pH control instrumentation and adjustable metering pumps. A well designed process control system is required to prevent overfeeding or underfeeding the neutralizing chemicals.

The primary disadvantage pertains to the necessity of handling acids and caustics.

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OXYGEN ENHANCED INCINERATION

Description

Oxygen enhanced incineration uses a specialized burner in conjunction with a rotary kiln for destruction of organic constituents in wastes. The burner uses oxygen or oxygen mixed with air to reduce fuel consumption and flue gas flow rates in the incinerator. The oxygen enhanced burner is capable of achieving higher temperatures than burners using air. The process has been demonstrated on a number of polynuclear aromatic compounds.

Applications

The process is applicable to organic constituents in solids, liquids and sludges. The oxygen enhanced incinerator uses a burner design which lowers flue gas flow rates for a given feed rate. The burner design lowers fuel consumption and allows higher operating temperatures. These factors make the oxygen enhanced incinerator particularly suitable for cases where fuel costs are high, oxygen is available relatively cheaply, and the waste feed has little or no heating value. The lower flue gas flow rates reduce particulate carryover from the incinerator and lower off gas treatment costs.

As with most incineration technologies, oxygen enhanced incineration has a neutral effect on metals and radionuclides. It is not applicable to wastes containing volatile or semi-volatile metals.

Advantages and Disadvantages

The advantages of oxygen enhanced incineration are that it is applicable to a variety of organic constituents, it is capable of lower operating costs than other incineration technologies in some cases, and that it is demonstrated, available technology. The oxygen enhanced incinerator has been demonstrated by EPA on soils containing numerous organic constituents, including polynuclear aromatics. Oxygen enhanced incineration technology has lower flue gas treatment costs and higher waste throughput than incineration technologies with conventional burners.

The primary disadvantage of oxygen enhanced incineration is that the burner is more difficult to control than conventional burners. If oxygen is not available at reasonable cost, the operating costs of the process can be high. Pilot testing is readily accomplished through a number of vendors, but bench testing is uncommon and of questionable value.

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POWDERED ACTIVATED CARBON

Description

The powdered activated carbon treatment (PACT) process incorporates biodegradation and physical adsorption to remove organic constituents from an aqueous stream. The reaction is carried out in an aeration basin. Powdered activated carbon added to the aeration basin adsorbs organics from the wastewater stream and acts as a substrate for microorganism growth. Non-biodegradable components remain adsorbed on the powdered activated carbon. A clarifier is used to separate treated water from spent powdered activated carbon and biomass. The powdered carbon is regulated until its adsorptive capacity is reached after which it is either regenerated or disposed of.

Applications

The process is applicable to aqueous streams with organic constituents concentrations ranging from 50 to 4,000 mg/l for large systems and up to 10,000 or 15,000 mg/l for small systems. Most organic constituents will be amenable to either biotreatment or adsorption onto the powdered activated carbon. PACT has been shown to reduce chemical oxygen demand by 93.5% and biochemical oxygen demand by 99.5%. Bench testing will be required to determine whether similar reduction efficiencies can be achieved for specific applications.

PACT is not applicable to treatment of heavy metals or radionuclides. While PACT is not directly applicable to contaminated soils, it may be possible to combine the process with soil washing or similar technologies.

Advantages and Disadvantages

The primary advantage of PACT is its applicability to a broad variety of organic constituents. It is commercially proven technology and is readily available. Vendor equipment is available for on-site regeneration of the powdered activated carbon. Bench testing is expected to be readily obtainable.

One potential disadvantage of PACT is that it may not remove some organic constituents to the degree necessary to achieve ARARs.

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PRECIPITATION

Description

Precipitation is the process of making dissolved chemical constituents insoluble so that they can be separated from the liquid (U. S. EPA, 1985; Wentz, 1989). Precipitation is usually accomplished by adding a chemical that forms an insoluble compound with the target contaminant. Hydroxide and sulfide precipitation are commonly used for removing heavy metals. Typical precipitating agents include sodium hydroxide, lime, ferric hydroxide, and sodium sulfide. The precipitates are often flocculated into larger particles (flocs) with the help of coagulants prior to solids removal.

Applications

The K-1232 Liquid Chemical Treatment Facility at Oak Ridge uses chemical precipitation for removal of heavy metals from plating operation aqueous wastes. The treated wastewaters are released under NPDES standards (Sferrazza, 1990).

An iron coprecipitation process has been used at Oak Ridge for removing uranium from nitrate-containing wastes and in the Uranium Mill Tailing Remedial Action (UMTRA) program for removing uranium, radium, and other contaminants from surface runoff wastes generated during remedial action. During pilot-scale testing of this process at Hanford, reduction of uranium in groundwater from 3,460 ppb to 1 to 7 ppb was demonstrated (Hodgson, 1989).

Advantages and Disadvantages

Chemical precipitation systems are relatively simple to operate and equipment and chemicals are readily available. However, the method generates a sludge that requires further treatment or disposal. If present, organometallic complexes may inhibit precipitation of the metals. There is no upper concentration limit for treatment but the lower concentrations are limited by equilibrium solubilities of the individual precipitates. The removal efficiencies are determined by the solubility products of the salts formed. However, some contaminants may be coprecipitated with the sludge that is formed, and may be removed to concentrations below their solubility limits. Treatability testing is generally required.

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RADIO-FREQUENCY HEATING

Description

Radio-frequency (RF) heating is an in-situ technology for volatilizing organic constituents in soil. Electrodes are installed in the contaminated zone and RF energy is applied to the soil. Through mechanisms of ohmic and dielectric heating, the soil temperature is raised and volatile and semi-volatile organic constituents are volatilized. Provisions are made for collection and treatment of the evolved vapors at the soil surface.

Applications

RF heating is applicable to numerous organic compounds in saturated and unsaturated soils. Compounds with boiling points of 500 degrees Fahrenheit or lower are effectively treated with this technology. RF heating does not destroy the organics, but facilitates their recovery from the soils by volatilization. Recovered organics can be treated by several methods.

The technology is not applicable to metals, radionuclides and some semi-volatile organics.

Advantages and Disadvantages

The advantages of RF heating include its applicability to numerous compounds and relatively low cost. Organic constituents with boiling points of 500 degrees Fahrenheit or less are amenable to treatment with this technology. The process is an in-situ method, which reduces the costs of excavation and disposal of treatment residue. The capital equipment should be easily relocated for treatment of multiple contaminant sites. RF heating has been successfully demonstrated on the commercial scale.

Disadvantages of the process include the inability to bench test and the high cost of the capital equipment. Some high boiling compounds are not amenable to treatment by this technology. Installation of the transmission electrodes in the contaminated soil has been identified as a potential source for personnel exposure and contaminant dispersion. Field experience is limited to a single full scale application.

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REVERSE OSMOSIS

Description

Reverse osmosis (RO) removes contaminants from aqueous wastes by passing the waste stream, at high pressure, through a semipermeable membrane. At typical operating pressures of 200 to 800 psi, clean water or permeate is forced through the membrane leaving a concentrated waste stream behind as membrane rejection. High pressure acts as the driving force to overcome the osmotic pressure created by higher concentrations of solutes in the rejection stream. The process produces a concentrated waste stream of reduced volume that requires further treatment or disposal.

Applications

Membranes in RO units are typically impermeable to fine particles and many dissolved species. In general, good removal can be expected for high molecular weight organics and charged anions and cations. Multivalent ions are treated more effectively than univalent ions (U. S. EPA, 1985).

The RO process has been developed and extensively applied for desalination of brackish waters (Dykes and Conlon, 1989) and in treating metal wastes from plating baths (U. S. EPA, 1986a). In addition to these more common applications for inorganics and metals, the technology has been applied for treating waste streams of organics and radionuclides.

Removal of organic contaminants from dilute waste streams were reported by EPA (U. S. EPA, 1985). Pilot-scale testing of an RO unit demonstrated 90 to 98 percent removal from the permeate for 1,2-dichloroethane, chloroform, diethyl ether, and tetrahydrofuran. Trichloroethene, benzene, bromoform, hexane, 1,1,1-trichloroethane, and 1,1-dichloroethane showed 99 percent or greater removal from permeate. PCBs and pesticides were also successfully removed from groundwater in test applications of a mobile RO unit at waste sites in Canada (U. S. EPA, 1986a).

RO was used by Hodgson and Garrett (1989) to treat groundwater containing a mixture of radioactive materials, including uranium and technetium, and nitrate. All contaminants in the effluent stream were reduced to concentrations below MCLs.

Advantages and Disadvantages

The primary advantage of RO is that this process can be used to successfully treat different types and combinations of contaminants in water to relatively low concentration levels.

Disadvantages are that contaminants are not destroyed by this process but are concentrated to a smaller liquid volume that still requires treatment or disposal. Pretreatment of the influent stream to prevent fouling, plugging, and chemical attack on the membrane is required.

This process also requires the use of cleaning solutions that will require treatment or disposal.

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ROTARY KILN INCINERATION

Description

A rotary kiln consists of an inclined, refractory lined, hollow cylinder which is rotated around its axis by an external drive mechanism. Material is fed into the kiln at the high end. The rotation of the kiln mixes the solids in the kiln and causes the solids to migrate to the low end of the kiln where they are removed. Rotary kilns are available in a variety of configurations, depending on the application and the nature of the feed material. Kilns may be fired co-currently (gas flow in the same direction as solids feed) or countercurrently. Operating temperatures may range from 1,400 to 2,000 degrees Fahrenheit for a normal operation, or from 2,200 to 2,500 degrees Fahrenheit for a slagging kiln. Combustion air and fuel (if required) are fed into one end of the kiln and off gas is recovered from the other end. The off gas requires treatment for control of emissions.

Applications

Rotary kiln incineration is applicable to organic constituents in a variety of waste matrices, including liquids, sludges and slurries, solids and gases. Slagging rotary kilns are applicable to solids with low softening point temperatures. Rotary kilns may be fired countercurrently to increase combustion zone turbulence, or co-currently to reduce particulate emissions. Some rotary kiln applications may require an afterburner in addition to off gas treatment. Wastes containing metals may require treatment of solid residuals to immobilize the metals.

Rotary kiln incineration has a neutral effect on metals and non-volatile radionuclides. The technology is not applicable to materials containing volatile or semivolatile metals.

Advantages and Disadvantages

Rotary kiln incineration is applicable to a wide variety of organic constituents. It is a well understood, commercially available technology. Rotary kilns may be adapted for use with a wide variety of waste types.

The technology has a neutral effect on most inorganics. It is not applicable to volatile or semivolatile metals nor to wastes with low softening points. Operating costs are moderately high because wastes with little or no heating value require addition of supplemental fuel. Pilot testing is readily accomplished through a number of vendors, but bench testing is uncommon and of questionable value.

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SOLVENT EXTRACTION

Description

Solvent extraction is used to remove organic constituents and some heavy metals from water, soil, or sludge. A solvent is chosen in which the contaminants of concern are soluble. The chosen solvent and the matrix to be treated are mutually insoluble. When the solvent and the waste are contacted, the contaminants of concern transfer from the waste matrix to the solvent. The waste and solvent are then separated. At this point, the waste matrix may be disposed or treated further, as appropriate. The solvent may be regenerated for reuse.

Applications

Solvent extraction is applicable to a wide variety of constituents. However, most solvents will be effective for particular types of constituents and will not be effective for other types. In addition, it is possible that some constituents may not be amenable to solvent extraction. Each system must be tested to select appropriate solvents.

Solvents containing extracted constituents should be regenerated, if possible, to allow economical treatment. This process does not destroy the extracted constituents. Further treatment of extracted constituents may be required prior to ultimate disposal.

The process is not applicable to constituents which may not be removed from the solvent during regeneration. Matrix conditions, such as pH, or the presence of surfactants or emulsifiers, may alter the effectiveness of the process.

Advantages and Disadvantages

The primary advantages of solvent extraction are its applicability to a wide range of contaminants and the widespread use of solvent extraction in industrial applications. Solvent extraction may be readily bench tested.

Costs of solvent extraction are higher than for absorption or stripping methods. In most cases, solvent extraction will be effective for a limited number of the constituents in the waste matrix, necessitating further treatment of the waste. Recovered contaminants will require treatment prior to disposal.

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STEAM STRIPPING

Description

Steam stripping involves injection of steam into a solution to volatilize the organic compounds in the solution. It can be operated as a batch or continuous process.

The batch process involves a batch still, an overhead vapor line, a condenser, a condensate receiver, and a gravity separator. Steam, injected through a perforated pipe in the still, provides the heat for vaporization of the waste. Vapor is condensed and collected as a liquid in the condensate receiver. Liquids with similar boiling points and different densities may be separated by gravity separation in the condensate receiver (U. S. EPA, 1987c).

In continuous steam stripping, waste flows down the column while steam flows up as in air stripping. The column is designed to promote transfer of contaminants to the gas phase by causing effective heat transfer to the waste, by creating turbulence in the waste, and by providing a large waste surface area. Different liquid-vapor equilibria exist at various heights in the column, with the highest relative concentration of the most volatile component being on the top (Blanney, 1986); however, all volatiles are swept out together in steam stripping.

Applications

Steam stripping is able to strip compounds with lower volatility than those removed by air stripping. The technology is reported to be effective for removal of high concentrations of organics, ranging from 1 to 20 percent (U. S. EPA, 1986a). Volatile organics, as well as semi-volatiles such as phenols, ketones, and phthalates, are good candidates for removal by steam stripping. Steam stripping is currently used at some commercial and industrial facilities to treat RCRA-spent solvent wastewaters (Turner, 1989). Hydrogen sulfide and ammonia can also be removed by this process (U. S. EPA, 1987c). Steam stripping is reported to be capable of removing over 99 percent of ammonia in high strength industrial wastes (Wickramanayake et al., 1989).

Advantages and Disadvantages

Steam stripping is a well demonstrated technology and commonly used in industry. As compared to air stripping, it may be used to treat less volatile compounds. However, the process generates a concentrate that requires treatment or disposal if recycling of the concentrate is not an option. This process is also expensive to operate, and is cost effective only when a source of waste heat or low cost fuel for producing steam is available.

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SUBMERGED AEROBIC FIXED FILM REACTOR

Description

The submerged aerobic fixed film reactor is a biodegradation system used for destruction of organic compounds in aqueous media. The process uses a bioreactor packed with plastic media which acts as a support for a film of bacterial growth. The packing is completely submerged in the bioreactor. Air or oxygen is pumped into the bioreactor to maintain aerobic conditions. In addition to oxygen, it may be necessary to add nutrients to the bioreactor for some applications. The submerged aerobic fixed film reactor requires less space than an aeration basin. This is due to the greater surface area provided by the bacterial film, and to the higher oxygen loading provided to the microorganisms.

Applications

The process is applicable to aqueous media contaminated with organic constituents which are amenable to biodegradation. The submerged aerobic fixed film reactor has been shown to be effective for relatively low concentrations in the influent stream. This is an advantage over other bioreactors, such as rotating biological contractors or aeration basins, which are not effective for low concentrations of organic contaminants. It may be necessary to combine the process with treatment of the bioreactor effluent by granular activated carbon for adsorption of non-biodegradable organic constituents.

Submerged aerobic fixed film technology is not applicable to radionuclides or heavy metals. Some metals have a toxic effect on the bacterial growth and must be avoided. Certain halogenated organic compounds are not readily destroyed by strictly aerobic biodegradation and are not amenable to treatment by this technology.

Advantages and Disadvantages

The primary advantages of the submerged aerobic fixed film reactor are applicability to a broad range of organic constituents, effectiveness for treatment of relatively low contaminant concentrations, and relatively low capital and operating costs.

The technology is not effective for all organic contaminants; it may be necessary to combine the process with a treatment technology for the bioreactor effluent.

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SUPERCRITICAL WATER OXIDATION

Description

Supercritical water oxidation uses oxygen dissolved in water above its critical point to oxidize organic compounds. Oxygen, from ambient air or from an oxygen source, is added to the water containing the organics to be treated. The water temperature and pressure are then raised above the critical point and rapid oxidation takes place. The heat released during oxidation is often sufficient to sustain the reaction. If the heat release is not sufficient, energy in the form of supplemental heat or organic compounds may be added to the water. Salts formed in the oxidation process generally precipitate out of solution. After the treated water is cooled and the pressure is released, off gases are released which may require treatment.

Applications

Supercritical water oxidation may be used to treat a variety of organic constituents, though it is less effective for halogenated compounds. Some work has been done with catalysts for treatment of halogenated compounds, however, the technology remains unproven for catalytic applications. The organics are partially oxidized to organic acids or completely oxidized to carbon dioxide and water. Sulfur containing compounds are oxidized to sulfate salts. Nitrogen containing compounds are reduced to elemental nitrogen. Oxidation temperatures are not sufficient for generation of nitrogen oxides (NO_x).

For many compounds, oxidation is not complete. Organic and/or fatty acids will remain as byproducts of the oxidation process. In most cases it would be expected that the toxicity of the organic compounds will decrease. Aromatic compounds are less easily oxidized by the supercritical water oxidation process.

The technology is not applicable to or economically feasible for treatment of water containing organic compounds in low part per million concentrations. The process is not applicable to radionuclides or heavy metals.

Advantages and Disadvantages

The primary advantage of supercritical water oxidation is that a variety of toxic organic constituents may be destroyed by low-temperature oxidation. Acid gases are easily controlled. The technology is proven at the commercial scale and equipment is readily available. Treatability testing may be conducted at the bench scale.

The primary disadvantages of supercritical water oxidation are that the technology does not effectively treat some organic constituents and it has high initial and operating costs. Some organic compounds are not completely oxidized; partially oxidized compounds may be more toxic than the original compounds in some cases. The technology may not provide for sufficient removal of some compounds which may be present in low concentrations.

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SURFACTANTS

Description

Surfactants in water alter the organic contaminants ability to adsorb onto the soil particles to promote solubilization of an essentially hydrophobic organic compound. One end of the surfactant molecule is polar (hydrophobic or water soluble) while the other end is nonpolar (hydrophylic, not water soluble). There are three types of surfactants - anionic, nonionic, and cationic. Anionic surfactants are highly soluble in water but are sensitive to the total ionic strength of the medial (soil particles like clays). Cationic surfactants are a small group of softening and coating agents that have positively charged solubilizing groups. Nonionic surfactants usually have a polyoxyethylene group as their solubilizing group and comprise the most commonly used group of commercial surfactants in North America (soaps and detergents).

Application

Used for organic contaminants in both unsaturated and saturated soils as well as above-ground batch soil washing processing. Surfactants in water are either injected or flooded onto a contaminated soil region to wash the soils in-situ in the vadose zone above the groundwater or within the contaminated groundwater itself.

Advantages and Disadvantages

An important advantage of surfactants is that water can be used as the extraction medium rather than organic solvents to transfer the organic from the soil into the liquid. They are generally inexpensive and much research is available on types as well as applications.

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THERMAL OXIDATION

Description

Thermal oxidation uses simple burner technology to produce a hot, oxidizing atmosphere for destruction of organic constituents in a gaseous medium. Most thermal oxidizers burn supplemental fuel to produce a flame in a combustion chamber. The incoming air stream passes through the combustion chamber with enough residence time to ensure destruction of the organics.

Applications

Thermal oxidation is applicable to a wide range of organic constituents in gaseous media. The process is not adversely affected by sulfur or halogens in the gas stream. However, off gases containing chlorinated hydrocarbons or sulfur will probably require off gas treatment for control of acid gases. In some cases it may be possible to recover heat from the off gases, but the additional energy cost may offset any savings.

The process is not applicable to metals or radionuclides. The system probably would not be cost effective for treatment of high-volume gas streams with little or no heat value (catalytic incineration would be better).

Advantages and Disadvantages

The primary advantages of thermal oxidation are its technical maturity and applicability to a variety of organic constituents. The technology is well developed and commercially available. Thermal oxidation can be used in combination with technologies which produce an off gas containing organics.

Thermal oxidizers can be quite expensive to operate if the gas stream to be treated has a high volume or if the gas has little heating value. Off gases containing halogens or sulfur probably will require treatment for control of acid gases. It would be relatively difficult to bench test an actual gas sample under conditions similar to those in the field.

References

Brunner, C. R. 1989. Handbook of Hazardous Waste Incineration. TAB Professional and Reference Books, Blue Ridge Summit, PA.

VACUUM EXTRACTION (AND STEAM INJECTION)

Description

Vacuum extraction is an in-situ treatment technology that involves air stripping of contaminants by inducing a vapor flow through the soil thereby displacing contaminated soil gas with uncontaminated gas. As air is pulled through the soil medium, organics which are in free phase, in solution, and sorbed onto the soil are volatilized into the air.

Vacuum extraction can be accomplished by installing perforated pipes, vertically or horizontally (depending on the depth to the water table), and exerting a vacuum through the soil using a pump. Implementation requires that certain geological as well as chemical characteristics are satisfied (Hutzler et al., 1990). Sandy soils and gravels are preferred, but vapor extraction may be used for silts and clays depending on degree of saturation. Since this technology involves transfer of the contaminants to the vapor phase, emission control must often be included as part of the system. Emission control systems can include activated carbon, catalytic oxidation, and thermal oxidation.

Less volatile compounds can be extracted by injecting steam into the soil to enhance the removal rate. In this case, the extracted organics can be condensed and recovered as a liquid.

Applications

Vacuum extraction is primarily applicable for removal of volatile organic compounds (VOCs) from soils above the water table (U. S. EPA, 1988a; Hutzler et al., 1990). Efficient removal by this technology requires contaminants of relatively high volatility. Contaminants with Henry's constants greater than 1×10^{-3} atm³/mole and vapor pressures greater than 1.0 mmHg indicate that vapor extraction may be suitable. Certain geological requirements, such as those specified above, must also be satisfied for vacuum extraction to be applicable.

Advantages and Disadvantages

The major advantage of vacuum extraction is that it is carried out in-situ so that the soil and underground structures can be left in place. The movement of air through the contaminated soil also promotes biodegradation of the contaminants. Additionally, the system is fairly easy to operate. The major disadvantage of this technology is that the contaminants are not destroyed, but transferred from soil to air, and additional aboveground treatment is, therefore, required.

References

Hutzler, N. J., J. S. Gierke, and B. E. Murphy. 1990. Vaporizing VOCs. Civil Engineering, 57-60. April, 1990.

U. S. EPA. 1988a. The Superfund Innovative Technology Evaluation Program: Progress and Accomplishments. EPA/540/5-88/001. February, 1988.

U. S. EPA. 1989, July. Terra Vac In Situ Vacuum Extraction System. Application Analysis Report. SITE Superfund Innovative Technology Evaluation. USEPA Research and Development. EPA 540 A5-89/003.

APPENDIX C
BENCH OR LABORATORY SCALE
TREATABILITY STUDIES STATEMENTS OF WORK

APPENDIX C
TREATABILITY STUDIES STATEMENTS OF WORK

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APPENDIX C

The evaluation of the technologies selected for treatability studies will be based on the relative effectiveness of the technology in reducing mobility, toxicity, and volume of the contaminated media in cases where more data are needed. The goal of these initial treatability studies will be to establish basic limitations of the technologies for use in the technologies and alternatives evaluation phases of the CMS/FS to be conducted at each OU.

All treatability studies will be performed according to data quality objective (DQO) levels II and III as defined by EPA guidance (U.S. EPA, 1987b). Analytical work associated with the treatability studies will follow the standard analytical protocol (EG&G Rocky Flats, 1990c) and quality assurance/quality control (QA/QC) procedures (EG&G Rocky Flats, 1990d) developed for the Rocky Flats Plan site.

The treatability testing will be performed with waste containing both average (mean) and high contaminant concentrations. Combinations of contaminants will also be studied where appropriate. Additional tests using synthetic mixtures may be used to supplement or support information from initial runs on original waste material and provide multivariable analyses where appropriate.

OXIDATION/REDUCTION

Introduction

This statement of work covers the bench-scale testing of oxidation/reduction processes to remove metals and radionuclides from surface water and groundwater at Rocky Flats. The review of existing data from OUs 1, 2, 4, 7, and 11 indicates that the metals barium, beryllium, lead, chromium, iron, mercury, nickel, selenium, and manganese and total gross alpha emitters such as americium, plutonium, tritium, and uranium are present in surface and groundwaters at Rocky Flats in concentrations which exceed possible action levels. Of these, chromium, mercury, and plutonium are known to be amenable to treatment by reduction processes, while iron is treated by oxidation processes. Treatability testing will be performed on site at the Rocky Flats Plant or at an off-site laboratory possessing the necessary licenses, approvals, and notifications to perform hazardous waste treatability studies and handle radioactive materials.

Test Objectives

The primary objective of this testing will be to evaluate the relative effectiveness of the following four technologies in removing metals and radionuclides from contaminated water:

- Oxidation/Precipitation
- Stannous chloride reduction
- Sulfur dioxide/metabisulfite reduction
- Ferrous sulfate reduction.

The testing of oxidation/reduction processes for metals and radionuclides will have the same two objectives: (1) oxidation/reduction of constituents to insoluble forms which can be readily removed from the water by settling or filtration and (2) oxidation/reduction to less soluble forms which can be subsequently removed by precipitation or coprecipitation, followed by settling or filtration. Thus, testing of the oxidation/reduction processes will be coupled with precipitation/coprecipitations and flocculation process testing to identify optimum metal and radionuclide removal efficiencies by oxidation/reduction.

OXIDATION/REDUCTION (Continued)

Test Approach

Oxidation/Precipitation

This test program will initially use small laboratory scale tests to oxidize and precipitate the heavy metals and radionuclides. Aeration will be used to add oxygen and precipitate iron. These initial tests will be done using multiple jar tests to determine the most effective type and dosage of coagulant and operating pH. The use of coagulant aids and polymers will also be evaluated.

Evaluation of performance during the initial tests will be based on visual observation of the rate of precipitate formation and settling. After the best apparent combinations of operating parameters has been established, additional tests will be performed with samples collected and analyzed to determine removal efficiencies. This will be followed by additional tests in which the precipitated and settled samples are filtered through 0.45 micron or smaller filter media to determine if increased removal efficiencies can be achieved.

If this process is demonstrated to be effective, pilot-scale testing during the individual operable unit CMS/FSs may be necessary to supplement these tests. At that time, sufficient quantities of sludges could be produced to evaluate alternative methods of treatment or disposal.

Reduction

Reduction tests will be conducted to evaluate the effectiveness of removing chromium, mercury, and plutonium from surface and groundwater. A series of jar tests will be conducted using the following reducing agents:

- Stannous chloride
- Sulfur dioxide/metabisulfite
- Ferrous sulfate.

Ionic mercury will be converted to the metallic form by reduction with stannous chloride and removed by filtration. Hexavalent chromium will be converted to trivalent chromium with sulfur dioxide, ferrous sulfate, or sodium metabisulfite. The conversion to trivalent chromium will be dependent on the time of reaction, pH of the reaction mixture, and concentration of the reducing agent. Removal of trivalent chromium is effected by precipitation.

OXIDATION/REDUCTION (Concluded)

The above reducing agents are also effective in reducing plutonium. Stannous chloride reduces plutonium (IV) to plutonium (III) and plutonium (VI) to plutonium (IV). Sulfur dioxide reduces plutonium (IV) to plutonium (III) and plutonium (V) to plutonium (IV). Ferrous sulfate reduces plutonium (IV) to plutonium (III). The less soluble forms are plutonium (III) and (IV).

Tests with each of the above reducing agents will be performed by varying the dosages of reducing agent ranging in concentrations from 20 to 300 percent in excess of the stoichiometric need of the target contaminants. A sample volume of 3 to 5 liters will be required for each jar test. Samples will be tested at different pH levels for each dosage of reducing agent. Effluent samples from each test will be split in two to be analyzed for metals and radionuclides separately. The effluent sample to be tested for metals will be precipitated following reduction. The one to be tested for plutonium will be subject to flocculation and settling after reduction.

PHYSICAL SEPARATION

Introduction

This statement of work covers the testing approach to evaluate physical separation as a pretreatment step prior to soil washing or solidification/stabilization treatments for contaminated soils. Although the technology is primarily targeted for inorganics, metals, and radionuclides, it may also be effective in reducing the volume of organics-contaminated soil.

Test Objectives

These tests will evaluate the effectiveness of physical processes to separate contaminated soil fractions from noncontaminated soil fractions and reduce the amount of material being treated by soil washing or solidification/stabilization technologies. Separations between types of contaminants may also be possible, allowing different treatments on different fractions. Tests will be conducted on the separation method and the size separation most likely to be useful in contaminated soil cleanup. Other physical separation processes, such as froth flotation and gravity (density) separation, have a limited range of applicability and may require feed characteristics that are unlikely to be found in contaminated soils. Preliminary characterization data, generated by sieve analyses, will be used to decide if size separation has a beneficial effect. Bench separations will be run if sieve analyses show isolation of contaminants of concern into a size fraction. These tests will provide sufficient information for the initial phases of the CMS/FS process and will also prepare enough product for soil washing and solidification/stabilization tests.

Test Approach

Testing will be conducted in two phases, a characterization phase and a confirmation - "production" phase. The characterization phase will consist of sieve analyses with chemical and radionuclide analyses on the individual size fractions. Complete disaggregation of all of the particles is essential to the accuracy of these analyses. If the contaminants of concern are concentrated in a particular particle size fraction (range of particle sizes) as shown by their distribution, then physical separation may be useful in treating the soils. If the size fractions with lower concentrations of contaminants of concern meet cleanup criteria, and they constitute the majority of the material, a significant volume reduction can be achieved by making the size separation and by treating a smaller volume of soil that has higher concentrations of contaminants. It is expected that, if there is a size separation effect, the contaminants will be concentrated in the finest fractions, i.e., silts and clays.

PHYSICAL SEPARATION (Continued)

The second phase of testing will have several purposes: primarily, confirmation of the results of the first phase; production of material for soil washing and solidification/stabilization tests; and development of data for pilot- and/or full-scale equipment sizing.

The first, or characterization, phase of physical separation testing will use a laboratory attrition scrubber to desegregate the soils to allow complete size separation. Attrition scrubbing is a process in which a water slurry containing a high concentration of solids is vigorously agitated. The particle=particle collisions in the slurry break up agglomerated fine materials and also scrub off fine particles that adhere to larger particles. The laboratory equipment typically available for attrition scrubbing cannot accept particles much larger than 2 millimeters; therefore, a preliminary wet screening step to remove large particles is necessary. This wet screening tends to wash fine particles off the large particles. While not as effective as attrition scrubbing, the residues of fines left on the coarse particles is generally insignificant. Wet screening is done on a vibrating screen with a continuous water wash. Either small vibrating screens (such as Sweco-type units) or standard sieves on a wet screen vibrator will be used as appropriate to the screen opening and amount of sample to be processed. Wet screening may be used at more than one stage of processing. The measurements of particle size distribution will follow the procedures described in ASTM D-422 (method for particle size analysis of soils), after the preparations described above.

The sequence of bench-scale testing of physical separation processing will include:

1. Soil sample preparation.
2. Wet screening/separation of large diameter soil particles (>2 millimeters [mm]).
3. Scrubbing of fine particles adhering to >2 mm fraction materials.
4. Analysis of water soluble contaminants, clay, and silt content using standard procedures (EG&G Rocky Flats, 1990c).
5. Screening to determine particle size distribution of fine (<2 mm) materials.
6. Analysis of contaminant distribution in the fine soil fractions using standard procedures (EG&G Rocky Flats, 1990c).
7. Evaluation of which contaminants are associated with the various size fractions.

PHYSICAL SEPARATION (Concluded)

The scrubbed size fraction greater than 2 mm would not be expected to contain a significant percentage of the constituents of concern. Depending on the percentage of total sample mass in the large size particle fraction, analysis for constituents of concern may be performed or may be omitted. The fraction of constituents not occurring in the scrubbing water and smaller size fractions may be assumed present in the greater than 2 mm material. Larger volumes of sample, as required to meet analytical and QA/QC requirements, will be used to verify initial results as to contaminant distribution and size gradations.

SOIL WASHING

Introduction

This statement of work covers testing of soil washing technologies for the removal of metals and radionuclides from contaminated soils either with or without preliminary physical separation. This statement of work is for laboratory- and bench-scale evaluations and does not cover field pilot testing.

Test Objectives

The objectives of this testing will be to evaluate several possible lixiviants and chelating agents for their effectiveness at removing contaminants of concern from contaminated soils, and to establish the best operating conditions for the effective agents. The effects of temperature, washing agent concentration, solid-liquid ratio in washing, and contact time will be investigated. Data will also be gathered on solid-liquid separation characteristics of the best systems. Loaded wash solution treatment and recycle/disposal issues will also be addressed.

Test Approach

The testing will be conducted in several phases; the results of each phase will be passed on to the next phase. Available physical and chemical data for soil will be used to guide the selection of washing agents to test.

The first phase of the test will be screening tests to identify the most promising washing agents. The screening tests will be batch shaker tests conducted under the ideal conditions for each washing agent, with before and after measurements of the concentrations of the contaminants of interest. The washing agents that are ineffective in reducing soil contaminant concentrations will be eliminated in this step, while the others will be tested further. The analytical work in this phase will focus on target contaminants, radionuclides, and metals.

The second phase of bench testing will be a series of wash tests conducted with one or more of the washing agents. The washing will be operated as a batch or sequential process to establish the optimum operating conditions for the process, including types and combinations of washing agents.

In the third phase of testing, conducted later as part of a CMS/FS for a specific OU, larger scale batch washes and small-scale continuous column washes will be conducted at the optimum conditions determined in Phase 2. These tests are used to provide data for pilot- and full-scale washing plant design, and to generate used wash liquor for recycling, treatment, and disposal testing.

SOIL WASHING (Concluded)

Initial Wash Tests

Sample volume: As required, to ensure that every liquid and solid product fraction will be large enough to meet analytical and QA/QC requirements.

Type of test: Batch wash test

These tests will be run with high strength wash solutions and at generally high temperatures and high liquid-solid ratios to ensure maximum possible removal of contaminants from the soils. These tests will provide screening data to allow elimination of ineffective washing agents.

The tests will be conducted in beakers with completely mixed heated equilibrium contacting of the washing liquid with the soil samples. Residual metal and radionuclide constituents in the soil and in the filtered wash liquid will be analyzed.

Wash Optimization

This phase will consist of bench-scale, batch washes at various solution strengths, temperatures and solid-liquid ratios followed by sequential washing with different agents to determine the probable optimum conditions for the individual washing agents or combinations of washing agents. The test plan to be developed will include appropriate means of effective liquid/solids separation to simulate real process conditions.

These optimization tests will be run with soil samples, and various sizes and ranges of wash liquid volumes, testing temperatures, and agitation times.

**ROCKY FLATS ENVIRONMENTAL RESTORATION PROGRAM
REVIEW/COMMENT RESOLUTION FORM**

Document No. and Title: DRAFT TREATABILITY STUDY PLAN (SEPTEMBER 21, 1990) Page 32 of

Reviewer Name(s): ENVIRONMENTAL PROTECTION AGENCY Date:

REVIEWER'S COMMENTS			RESPONSE
COMMENT NO.	PAGE NO.	COMMENTS	DISCUSSION
8	6	Section 6.2, page 6-19. The guidelines provided will require some revision to reflect verbal comments on incorporating and/or amending SOP/QAPJP requirements. A detailed, annotated standard outline should be provided for Treatability Study Work Plans. Interim reports on specific studies will be reviewed if provided by DOE, but the final result of this program as required by the IAG is a comprehensive report, for which an outline (based on Table 6-2) should be provided.	<p>Section 6 does represent a detailed, annotated outline for the Treatability Study work Plans.</p> <p>The outline for the Final Treatability Studies Report is included as Table 6-2 and is based on EPA Guidance for Conducting Treatability Studies under CERCLA.</p>

SOLIDIFICATION/STABILIZATION

Introduction

This statement of work covers testing of solidification/stabilization agents for treatment of soils contaminated with metals and radionuclides of concern. Included in this program is the testing of these agents on contaminated soil fractions that have been separated from the bulk of the soil by physical means. Agents to be tested will include portland cement-based, epoxy polymer-based and polyester polymer-based, masonry cement-based, and pozzolan-based agents. Testing of proprietary formulations may involve off-site tests at vendors' laboratories or on-site tests by vendor personnel. Companies that offer off-site laboratory solidification testing include International Waste Technologies (IWT) and Hazcon. This plan covers laboratory characterization and bench scale testing of mixtures for leaching, strength and durability characteristics. It does not include field pilot-scale testing.

Test Objectives

The objectives of this program are to evaluate solidification/stabilization agents and additives to determine if contaminants in soils can be sufficiently immobilized by their use to meet regulatory criteria for disposal or replacement. Mixtures of contaminated soils and stabilization agents will be tested for leaching, strength, and durability characteristics. The results of these tests will be compared to regulatory and other criteria that may be applied in determining how the soil is to be handled. Leaching characteristics are important in determining whether the material can be left on-site or must go to a solid waste or hazardous waste landfill. Strength and durability criteria are imposed by some off-site landfills and will affect the design of any on-site repositories.

The tests will be focused on immobilization of heavy metals and radionuclides, but leaching of organic constituents will be tested to determine whether further treatment would be required.

Test Approach

The test approach assumes that leaching criteria are the most important; the agents and formulations are screened based on leaching results. Formulations that pass the leaching tests will then be tested for their performance regarding the strength and durability criteria.

Screening Tests

The screening tests will be conducted on the widest range of formulations, but only small amounts of soil will be required for each test. The soil samples will be mixed with the various agents at three different ratios with water being added in constant proportion to the amount of stabilization agent. A

SOLIDIFICATION/STABILIZATION (Continued)

relatively short curing time of 24 hours will be used for comparison of leaching characteristics; however, longer cures will be used in the formulation optimization tests when strength characteristics are compared. After curing, the samples will be subjected to the appropriate leach procedure. The leachates will be analyzed for the contaminants of concern.

Solidification/stabilization agents that will be tested include portland cement, polyester polymers, and epoxy polymers. Ratios of soil to stabilization agent will be varied over the range of 1:1 to 4:1. The ratio of water to stabilization agent will be kept constant for each agent. Different dosages of additives will also be tested with the dosage ranges based on recommendations from the proprietary vendors.

The leach test protocols will be determined by the regulatory requirements and cleanup goals for the soils in question. The Toxicity Characteristics Leaching Procedure (TCLP) is most likely to be the required leach test for RCRA hazardous materials, while the American Nuclear Society Short-Term Test procedure (ANSI/ANS-16.1-1986) may be applicable to radioactively contaminated soils and soils with mixed radioactive and hazardous contaminants.

The results of the leach tests will be used to select the agents and additives that will be used for formulations optimization. The formulations that meet leachability standards at lowest probable cost will be the starting points for further development.

Formulation Optimization

The results of the screening tests will be used to select a limited number of solidification agents for which optimum formulations will be developed. The optimization may depend more on physical criteria rather than leaching criteria. Sample volume requirements will depend on the amounts of stabilized material needed for the various tests. Typically, 1 kg of mixture will be required for one TCLP leach and one unconfined compressive strength test. Standard cure times of 7 and 28 days will be used for all the physical characterization samples at this stage. Use of two cure times will allow comparison of the test mixtures on rate of development of strength and durability characteristics. Multiple cures will be tested for each mixture and cure time to gain information on variability of the characteristics achieved.

The leaching tests in this phase will follow the same protocols as in the screening tests. In addition, the basic unconfined compressive strength tests will be conducted as outlined in ASTM Standard D-2166. If durability of the solidified material is determined to be of importance, standard tests such as Methods for Freezing-Thawing Test for Soil-General Mixtures (ASTM D-560-82), Methods for Wetting and Drying Tests for Compacted Soil-General Mixtures (ASTM D-559-82), and Test Method for Slake Durability of

SOLIDIFICATION/STABILIZATION (Continued)

Stakes and Similar Weak Rocks (ASTM D-4644) may be required. The goal of this testing is to find the lowest probable cost formulation that meets all of the soil cleanup criteria.

Confirmation Tests

To support the evaluation of this technology for CMS/FSs which are scheduled to be conducted after the sitewide study is completed, one or two formulations will be selected as optimum based on the formulation/optimization results and a final batch of that formulation will be mixed for confirmation by all relevant tests using DQO levels IV and V. A large batch of at least 5 kilograms will be required. From that batch, the various samples will be split before the mixture sets.

The same test criteria will be applied in this phase as in the previous phases. The primary differences will be in the amount of solidified mixture prepared and the level of QA/QC required. This phase will be essential in providing more definitive data on the performance

Test Objectives

The objectives of this program are to evaluate solidification/stabilization agents and additives to determine if contaminants in soils can be sufficiently immobilized by their use to meet regulatory criteria for disposal or replacement. Mixtures of contaminated soils and stabilization agents will be tested for leaching, strength, and durability characteristics. The results of these tests will be compared to regulatory and other criteria that may be applied in determining how the soil is to be handled. Leaching characteristics are important in determining whether the material can be left on-site or must go to a solid waste or hazardous waste landfill. Strength and durability criteria are imposed by some off-site landfills and will affect the design of any on-site repositories.

The tests will be focused on immobilization of heavy metals and radionuclides, but leaching of organic constituents will be tested to determine whether further treatment would be required.

Test Approach

The test approach assumes that leaching criteria are the most important; the agents and formulations are screened based on leaching results. Formulations that pass the leaching tests will then be tested for their performance regarding the strength and durability criteria.

SOLIDIFICATION/STABILIZATION (Concluded)

Screening Tests

The screening tests will be conducted on the widest range of formulations, but only small amounts of soil will be required for each test. The soil samples will be mixed with the various agents at three different ratios with water being added in constant proportion to the amount of stabilization agent. A relatively short curing time of 24 hours will be used for comparison of leaching characteristics; however, longer cures will be used in the formulation of this process at full scale. The results of this test phase may also indicate any unusual behavior that could be encountered in scale up of the process.

ADSORPTION

Introduction

This statement of work covers the bench-scale testing of adsorption processes to remove metals and radionuclides from surface water and groundwater at Rocky Flats. The review of existing site data indicate that the metals beryllium, chromium, iron, lead, manganese, mercury, and selenium and total gross alpha emitters such as uranium, plutonium, and americium are present in groundwaters and surface waters at Rocky Flats in concentrations which exceed possible action levels. All of these species are potentially amenable to treatment by adsorption. Treatability testing will be performed on site at the Rocky Flats Plant or at an off-site laboratory possessing the necessary licenses, approvals, and notifications to perform hazardous waste treatability studies and handle radioactive materials.

Test Objectives

The primary objective of this testing will be to evaluate the effectiveness of adsorbent materials for removal of metals and radionuclides from water. The testing for all species will have the same objectives: to establish that the species is amenable to treatment using adsorption columns, to screen appropriate adsorbent materials in order to select the most suitable materials, and to establish bench scale design information such as adsorbent capacity and breakthrough behavior. The ability to regenerate the adsorbents, as applicable, will also be tested. Given the range of contaminants to be treated it is likely that a broad range of adsorbent materials will be tested. This will include readily available materials such as granular activated carbon, activated alumina, bone char, zeolites, and soils. The use of proprietary specialty adsorbents such as Filox which were developed for treatment of specific contaminants will also be investigated.

Test Approach

The test program will use small bench scale columns of adsorbent materials to test the removals of metals and radionuclides. When a potentially suitable set of adsorbent materials for treatment of a specific contaminant has been selected an initial screening test will be conducted. During this test contaminated water will be pumped through a set of columns, each column containing a different adsorbent material. The discharge from each column will be collected separately and analyzed for the metals and radionuclides present in the feed water. The one or more materials which show the best performance for removal of the contaminant will be tested again during which more detailed information on adsorbent capacity will be obtained. If possible a breakthrough curve for the contaminant will be established. If it is practicable to test the regeneration of the adsorbent after the adsorption testing this will be done.

ULTRAFILTRATION/MICROFILTRATION

Introduction

This statement of work covers the bench-scale testing of ultrafiltration and microfiltration processes to remove metals and radionuclides from surface water and groundwater at Rocky Flats. The review of existing site data indicate that the metals beryllium, chromium, iron, lead, manganese, mercury, and selenium and total gross alpha emitters such as uranium, plutonium, and americium are present in groundwaters and surface waters at Rocky Flats in concentrations which exceed possible action levels. All of these species are potentially amenable to treatment by filtration. Treatability testing will be performed on site at the Rocky Flats Plant or at an off-site laboratory possessing the necessary licenses, approvals, and notifications to perform hazardous waste treatability studies and handle radioactive materials.

Test Objectives

The primary objective of this testing will be to evaluate the effectiveness of ultrafiltration and microfiltration for removal of metals and radionuclides from water. The testing for all species will have the same objectives: to establish that the species is amenable to treatment using ultrafiltration or microfiltration, to screen appropriate chelating agents in order to select the most suitable agents, and to determine the optimum chelating agent doses and solution pH for maximum contaminant removal. The removal efficiencies achieved by filtration will be determined. Given the range of contaminants to be treated it is likely that a broad range of high molecular weight chelating agents will be tested.

Test Approach

The test program will use small bench scale tests to chelate the metals and radionuclides and filter the chelated contaminants for the water using microfiltration or ultrafiltration membranes. Initial testing will involve multiple jar tests using all potentially applicable chelating agents at the estimated best dose and at a number of different pH levels. These samples will then be filtered and the filtered water analyzed for metals and radionuclides.

The four chelating agents which produced the best removals during the initial tests will be subjected to a second round of testing. The most effective dosage of chelating agent and operating pH will be established during this second round of testing.

TRU/CLEAR™

Introduction

This statement of work covers the bench-scale testing of the TRU/Clear™ process to remove radionuclides from surface water and groundwater at Rocky Flats. TRU/Clear™ is the brand name for a proprietary precipitating agent based on the use of ferrite ions. The review of existing site data indicate that total gross alpha emitters such as uranium, plutonium, and americium are present in groundwaters and surface waters at Rocky Flats in concentrations which exceed possible action levels. All of these species are potentially amenable to treatment using TRU/Clear™. Treatability testing will be performed on site at the Rocky Flats Plant or at an off-site laboratory possessing the necessary licenses, approvals, and notifications to perform hazardous waste treatability studies and handle radioactive materials.

Test Objectives

The primary objective of this testing will be to evaluate the effectiveness of the use of TRU/Clear™ in removal of radionuclides from water. The tests will also have the objective of establishing the correct dosage and operating pH for the use of TRU/Clear™ and to determine the removal efficiencies which can be obtained by a combination of addition of TRU/Clear™ with either solids settling or filtration.

Test Approach

The test program will use small bench scale tests to remove the radionuclides using TRU/Clear™. Initial testing will involve multiple jar tests using different dosages of TRU/Clear™ at a number of different pH levels. In one round of tests the solids will be allowed to settle and the supernatant water analyzed for radionuclides to determine removal efficiencies. In a second round of tests the samples will be filtered and the filtered water analyzed for radionuclides again to determine removal efficiencies. The most effective operating conditions for the TRU/Clear™ process will be established in this fashion.

ION EXCHANGE

Introduction

This statement of work covers the bench-scale testing of ion exchange processes to remove metals and radionuclides from surface water and groundwater at Rocky Flats. The review of existing site data indicate that the metals beryllium, chromium, iron, lead, manganese, mercury, and selenium and total gross alpha emitters such as uranium, plutonium, and americium are present in groundwaters and surface waters at Rocky Flats in concentrations which exceed possible action levels. All of these species are potentially amenable to treatment by ion exchange. Treatability testing will be performed on site at the Rocky Flats Plant or at an off-site laboratory possessing the necessary licenses, approvals, and notifications to perform hazardous waste treatability studies and handle radioactive materials.

Test Objectives

The primary objective of this testing will be to evaluate the effectiveness of ion exchange treatment for removal of metals and radionuclides from water. The testing for all species will have the same objectives: to establish that the species is amenable to treatment using ion exchange columns, to screen appropriate ion exchange materials in order to select the most suitable ion exchange resins, and to establish bench scale design information such as resins capacity and breakthrough behavior. The ability to regenerate the resins, as applicable, will also be tested. Given the range of contaminants to be treated it is likely that a broad range of ion exchange materials will be tested including both strong and weak anion and cation exchange resins and perhaps chelating resins as well. The use of specialty ion exchange resins which were developed for treatment of specific contaminants will also be investigated.

Test Approach

The test program will use small bench scale columns of ion exchange materials to test the removals of metals and radionuclides. When a potentially suitable set of ion exchange materials for treatment of a specific contaminant has been selected an initial screening test will be conducted. During this test contaminated water will be pumped through a set of columns, each column containing a different ion exchange material. The discharge from each column will be collected separately and analyzed for the metals and radionuclides present in the feed water. The one or more resin materials which show the best performance for removal of the contaminant will be tested again during which more detailed information on resin capacity will be obtained. If possible a breakthrough curve for the contaminant will be established. If it is practicable to test the regeneration of the resin after the adsorption testing this will be done using an acid or sodium salt solution for cation exchange resins and a caustic or chloride salt solution for anion exchange resins.

MAGNETIC SEPARATION

Introduction

This statement of work covers the laboratory and bench-scale testing of the magnetic separation process to remove radionuclides from soil at Rocky Flats. Magnetic separation can be used to separate radionuclide particulate species which have significant magnetic susceptibility (such as PuO) from the bulk soil fraction. The process separates out a small volume of soil containing the majority of the radionuclides from the larger volume of depleted soil. Magnetic separation may be used in combination with size separation to achieve greater decontamination. Treatability testing will be performed on site at the Rocky Flats Plant or at an off-site laboratory possessing the necessary licenses, approvals, and notifications to perform hazardous waste treatability studies and handle radioactive materials.

Test Objectives

The primary objective of this testing will be to evaluate the effectiveness of the magnetic separation process in the removal of radionuclides from the soil. The effects the soil's composition on this process will be investigated. Data will also be gathered on the volume reduction factor, based on the volume of soil processed versus the volume of decontaminated soil.

Test Approach

The test program will use laboratory and bench scale tests to remove the radionuclides. Initial testing will be conducted to develop the operating parameters for the system. In the second round of test the samples will be analyzed to determine removal efficiencies and the most effective operating conditions for the process.

TRU CLEAN™

Introduction

This statement of work covers the bench-scale testing of the TRU Clean™ process to remove radionuclides from soil at Rocky Flats. TRU Clean™ is the brand name for a proprietary process that sends contaminated soils through an array of machinery which separates the radioactive contaminants from the host soils. Treatability testing will be performed on site at the Rocky Flats Plant or at an off-site laboratory possessing the necessary licenses, approvals, and notifications to perform hazardous waste treatability studies and handle radioactive materials.

Test Objectives

The primary objective of this testing will be to evaluate the effectiveness of the TRU Clean™ method in removal of radionuclides from soil. The effects of size and soil type will be investigated. Data will also be gathered on the volume reduction factor, based on the volume of soil processed versus the volume of decontaminated soil.

Test Approach

The test program will use small bench scale tests to remove the radionuclides using the TRU Clean™ process. Initial testing will be conducted to develop the operating parameters for the TRU Clean™ system with this soil type, screening and sizing. In the second round of test the samples will be analyzed to determine removal efficiencies and the most effective operating conditions for the TRU Clean™ process.

APPENDIX D
INTER-AGENCY AGREEMENT DEFINITION OF
TREATABILITY STUDY PLAN

Treatability Study

Within 180 days of the effective date of this Agreement, DOE shall submit a Treatability Study Plan for joint approval by EPA and the State, detailing the study of methods potentially available for use in Corrective/Remedial action for each type of waste/waste matrix in sites at the Rocky Flats Plant. The Treatability Study Plan shall identify candidate technologies for evaluation in a treatability studies program and shall cover the range of technologies required for alternative analysis during the CMS/FS. In the event site characteristics require the evaluation of additional treatability studies, DOE shall perform the EPA and the State required treatability studies in addition to the work defined within the Treatability Study Plan required by this paragraph. Within the Treatability Study Plan, DOE shall submit information on performance, relative costs, applicability, removal efficiencies, operation and maintenance requirements, and implementability of candidate technologies in addressing the below listed general types of wastes. If practical candidate technologies have not been sufficiently demonstrated, or cannot be adequately evaluated by EPA and the State on the basis of existing information, the Treatability Study Plan shall propose a Treatability Study for the candidate technology(s). To this end, the Treatability Study Plan will propose a statement of work for the specific Treatability Study Plan will propose a statement of work for the specific Treatability Study(s) to be performed. The Treatability Study Plan will outline the steps and data necessary to evaluate and initiate the treatability testing program, test objectives, data quality objectives, experimental procedures, treatability conditions to be tested, measurements of performance, analytical methods, data management and analysis, health and safety, and residual waste management. If the quality assurance project plan (QAPP) and/or the field sampling plan (FSP) required in Attachment condition VI.B do not adequately define or address the investigations to be conducted during the Treatability Study, then the Treatability Study Plan will incorporate an amended QAPP and FSP specific to the Treatability Study. The treatability study program shall not be initiated until EPA and the State have reviewed and jointly approved, in writing, the Treatability Study Plan.

The Treatability Study shall be initiated within 30 days of joint approval by EPA and the State. This study shall evaluate applicable technologies for the general types of wastes anticipated at the Rocky Flats Plant. The general types of wastes/waste matrices to be included in the study include: volatile and semi-volatile contaminated wastes, soils, surface water and groundwater; metal contaminated wastes, soils, surface water and groundwater; radioactive wastes, soils, surface water and groundwater, and; any combination of the above listed general types of wastes.

The Treatability Study shall be completed and the results shall be submitted to EPA and the State within 36 months of the approval of the Treatability Study Plan by EPA and the State. Additional Treatability Studies may be proposed by DOE, or required by EPA and the State if, at any time it is determined that additional studies are required. Additional studies shall be initiated by submission of amendments to the Treatability Study Plan, for EPA and State review and approval.

**COMMENT/RESOLUTION SUMMARY OF
EPA AND CDH COMMENTS ON SITEWIDE
TREATABILITY STUDIES PLAN**

COMMENT/RESOLUTION SUMMARY OF
EPA AND CDH COMMENTS ON SITEWIDE
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Reviewer Name(s): COLORADO DEPARTMENT OF HEALTH Date:

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General 1	1	<p>December 21, 1990</p> <p>Mr. Robert M. Nelson, Jr., Manager Department of Energy Rocky Flats Area Office P.O. Box 928 Golden, CO 80402-0928</p> <p>Mr. James O. Zane Rocky Flats Plant Manager EG&G Inc. P.O. Box 464 Golden, CO 80402-0464</p> <p>Gentlemen:</p> <p>Attached are the Colorado Department of Health, Hazardous Materials Waste Management Division, ("The Division"), comments on the Draft Treatability Studies Plan submitted September 21, 1990.</p> <p>The purpose of writing a "draft Treatability Studies Plan" is to screen both practical conventional and innovative technologies to determine the technologies which need the additional information gained by performance of treatability studies. The screening process is a comprehensive literature search on each technology, followed by application of appropriate Rocky Flats contaminate levels and types which should result in the elimination of some technologies as being inappropriate for Rocky Flats and other technologies for having sufficient information available to eliminate them from the treatability study process. "The Division" finds it difficult to believe that only three technologies have</p> <p>The Treatability Studies Plan now includes innovative/emerging technologies.</p>

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		<p>sufficient information available to eliminate them from the "treatability study" process. The major flaw in the screening process used by DOE and EG&G is that the "procedure for technology selection and screening" figure 5-1 page 5-2 is not an accurate interpretation of the screening process outlined in the EPA Guide for Conducting Treatability Studies Under CERCLA EPA/540/2-89/058, page 9 Figure 2. A copy of both flow diagrams is attached. The rearrangement and addition of steps in the selection and screening process results in performance of treatability studies for almost every technology. In fact, only three of the twenty-two "practical" standard conventional technologies evaluated are judged to have enough information available to avoid treatability studies.</p> <p>DOE's screening process substitutes "Evaluate existing site data" with "site characterization data", the difference being that all the site characterization data will not be available for several more years. The DOE screening process adds "identify potential ARAR's", of which there is not mention in the IAG Statement of Work definition of Treatability Study. The biggest hole in the DOE screening process is opened by the replacement of "Search Literature to determine data needs", with DOE's "determine Data needed for screening". By not performing a comprehensive literature search before identifying data gaps almost every technology must fall into the "Conduct Treatability study" block.</p> <p>In addition, the Interagency Agreement (IAG), Statement of Work, page 39 XI, Treatability Study states, "Within the Treatability Study Plan, DOE shall submit information on performance, relative costs, applicability, removal efficiencies, operation and maintenance requirements, and implementability of candidate technologies in addressing the below listed general types of waste." Each of these six parameters must be addressed for each of</p>	<p>The selection and screening process has been revised as suggested.</p> <p>ARARs must be considered in selecting and evaluating technologies since they define the contaminants of concern and the target treatment goals. A comprehensive literature search was used to identify and screen technologies.</p> <p>The screening process has been revised to include these six parameters.</p>

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		<p>the candidate technologies. The information submitted in the Appendix C Technology Data Sheets is incomplete.</p> <p>There are no innovative new technologies screened in the plan. EG&G's two phase approach is not acceptable to "the Division." At a minimum, all of the technologies currently under review by the DOE's Office of Technology Assessment should be included in the Treatability Studies Plan.</p> <p>The "Division" will not approve the Final Treatability Studies Plan unless the above concerns are addressed.</p> <p>If you have any comments regarding our comments please contact Noreen Matsuura at 331-4920.</p> <p>Sincerely,</p> <p>Gary W. Baughman Unit Leader Hazardous Waste Facilities Hazardous Materials and Waste Management Division</p> <p>cc: Thomas T. Olsen, DOE Scott Grace, DOE Tom Greengard, EG&G Gary Anderson, EG&G Martin Hestmark, EPA Arturo Duran, EPA Teresa Hamoton, AGO</p>	<p>The Technology Data Sheets have been expanded.</p> <p>Innovative/emerging technologies have been included in the revised TSP.</p>

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		Innovative/emerging technologies have been included in the revised TSP.
2	1	The figure has been revised.
3	1	Screening criteria includes consideration of whether or not additional data is required to evaluate and screen technologies.
4	1	The TSP conforms to the requirements of IAG Section XI.
5	1	Section 5.0 has been revised.

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6	1	Only the technologies which need Treatability Studies need to have Treatability Study Work Plans and the subsequent Treatability Study Reports after the treatability study is performed.	Agree.
7	1	Figure 5-1 Technology Selection and Screening Process page 5-2. Enclosed is a copy of the analogous flow chart from the EPA Guidance document as cited in the transmittal letter. This guidance document is listed in the bibliography, and it remains a puzzle why it is not used in writing this document.	This figure has been revised.
8	1	It is not necessary to have complete site characterization data to identify applicable technologies.	Site characterization data, along with ARARs, is necessary to determine what has to be "treated." This information, plus literature review, data base search, etc., was used to identify potential technologies.
9	1	By not doing a comprehensive literature search before deciding whether enough data is available almost every technology must have treatability study performed on it.	ARARs are an essential element in determining what technologies need to be considered.
10	1	Section 5.1.2 ARAR Identification. It is not necessary to spend a lot of time determining ARAR's since they will be site specific and probably change between now and the time the site is actually remediated. IRIS, the risk assessment data base provides health based levels which are updated regularly. The use of IRIS for this and other site-wide documents where some information on ARARs is useful is recommended.	
11	2	Section 5.2.2. Practical Technologies and Applications, page 5-17. Each of the 26 technologies for water and 16 technologies for soil should have been evaluated on the basis of the six points listed in the IAG (Information on performance, relative cost, applicability,	Screening criteria has been revised as suggested.

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14	2	<p>The six points listed in the IAG have been included in the screening process.</p> <p>It is not possible to provide quantitative, cost or removal efficiency information at this stage of technology evaluation.</p>
15	3	<p>The six points listed in the IAG have been included. Innovative/emerging technologies have also been added to the screening process.</p>

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12	2	<p>removal efficiencies, operation and maintenance requirements, implementation of technology).</p> <p>Section 5.2.2.1 Water Technologies, page 5-18. Combination of contaminants in media should have been addressed in a more specific manner in this section. For example, on page 4-6, the discussion of contaminants present at 881 Hillside lists radionuclides, chromium, iron, and three volatile chlorinated organics present in the soil. What technology or combination of the technologies could be used to remove all three types of contaminants and what order should the technologies be performed in to minimize cost and maximize removal efficiencies? There are chemical simulating process modeling systems available which given specific input and output concentrations would produce information on all six of the decision parameters listed in the IAG. It is not necessary to perform treatability studies on every technology when information is available in modeling programs or in a comprehensive literature search, in a more timely fashion than 36 months.</p>	<p>The site-wide TSP is not intended to address unique combinations of contaminants applicable to a specific OU. The site-wide TSP is also not intended to minimize costs or maximize performance. This level of effort must be done at the OU-specific level.</p>
13	2	<p>Section 5.2.2.2 Soil Technologies, page 5-24. The factual content of the soil technologies presented in these three pages could be summarized in the following sentence.</p> <p>Solidification/stabilization, soil washing and physical separation technology may be applied to soil contaminated with radionuclides and inorganics, organics may be removed by vacuum extractions, incineration, thermal desorption, or biological treatments in a slurry reactor, land farming, or in situ, an expensive method for treating radionuclides in soil is vitrification. It is difficult to believe that none of these technologies has been used at any other site on earth and no data is available on effectiveness, cost etc.</p>	<p>This section does not state that the technologies listed have not been used at other sites and no data exists.</p>

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		<p>must be rescreened after a thorough literature search so that all of the technologies not need to undergo treatability studies. The technologies which have been determined to need treatability studies must have specific treatability study workplans outlined. The workplan should include a technology specific experimental procedure, not the content outline of an experimental procedure copied from the treatability study guidance. The workplan must include a data goal, for example a solubility, partition coefficient, reaction rate constants, etc. There are ten parameters for a treatability study workplan outlined in the IAG. For each technology chosen for a treatability study, a treatability study workplan which addresses all ten of the parameters listed in the IAG must be included in the final treatability study. The "division" does not intend to approve EPA's Guide for Conducting Treatability Studies under CERCLA 540/2-89/053 as the Final Site Wide Treatability Studies Plan for Rocky Flat document.</p>	<p>Detailed workplans for each technology selected for the TSP will be prepared later.</p>

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1	1	<p>General. The content of the treatability studies plan (TSP) does not entirely fulfill the scope of work presented in Article XI, Attachment 2, of the IAG. The TSP does not include information on relative costs, removal efficiencies, operation and maintenance requirements, or implementability of all candidate technologies. Similarly, the TSP does not discuss analytical methods, data management and analysis, health and safety, and residual waste address these issues for the screening and selection of candidate technologies for remedial alternatives and design.</p> <p>Screening criteria now includes removal efficiency, operation and maintenance requirements, residuals and implementability. Costs are considered indirectly in operation and maintenance and were not considered directly since this is very site specific and since innovative technologies were considered for which little or no cost data is available. Analytical methods, data management and analysis and health and safety are not significant screening criteria at this stage of the process.</p>
2	1	<p>General. The TSP differentiates between practical technologies and emerging/innovative technologies. However, the current document only discusses practical (demonstrated, conventional) technologies. Site-wide treatability studies should include all technologies potentially applicable to mitigation of contamination at the site. Identification and evaluation of emerging/innovative treatment technologies should be discussed in the TSP. This should include provisions to evaluate potentially applicable technologies identified after the TSP is finalized.</p> <p>Emerging/innovative technologies have been added to the screening process.</p>
3	2	<p>General. Applicable or relevant appropriate requirements (ARARs) should be identified during the screening of potential technologies before treatability testing. Chemical-, action-, and location-specific ARARs may restrict implementability of a particular technology at the site or indicate how a selected alternative must be implemented. As part of the TSP, these ARARs will affect the screening of potential technologies in the Final Treatability Studies Plan (see Appendix A and Table 4-2). Location and action-specific ARARs were not selected as they would provide little information on how effectively a technology treats waste.</p>

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4	2	<p>selection of candidate technologies for treatability studies, remedial alternatives development, design, and action.</p> <p><u>General.</u> Cleanup goals for target chemicals or waste groups should be defined in the ISP. The basis for evaluating the effectiveness of a treatment technology is to calculate removal efficiencies and compliance with established cleanup criteria (based on ARARs, see comment 3). Similarly, data quality objectives should be established in the ISP to define the data quality needs of the treatability studies program.</p>	<p>This issue arises at nearly every Superfund Site. The reviewer is correct in concept; however, from a practicability perspective, the concern cannot be addressed at this time because site-specific cleanup goals (action levels) will not be calculated until the early stages of the Feasibility Study. This is because the Baseline Risk Assessment (BRA) is required in order to identify the chemicals and pathways of concern as well as to identify the individual chemical/pathway/media risk contributions. As a practicable alternative, preliminary target cleanup goals can be established at MCL's for groundwater. This will allow the study to be conducted on the basis of the likely range of cleanup goals that technologies will have to achieve.</p>
1	2	<p><u>Specific Comments</u></p> <p>Page 3-1, Paragraph 2. The text states that protocol for conducting treatability tests are required to ensure the data collected are accurate, complete and appropriate. A usual objective in data collection is to obtain measurements and samples that meet acceptable standards of accuracy, precision, comparability,</p>	<p>The goal of treatability studies, as will be stated in individual TSFs, is to evaluate a particular technology's capability to reduce contaminants and to determine whether the treatment may have undesirable effects. The removal efficiency of the technology will be based on established criteria including established background levels or ARARs, both of which are presented and discussed in TSFs. Data quality objectives will be established in the Quality Assurance Addendum that will be developed for each TSP. The relationship between the QAPJP and QAAs is explained in Section 6.12. The content of the QAPJP and QAAs is also now summarized in this section.</p> <p>A Quality Assurance Addendum to the Site-Wide Quality Assurance Project Plan (QAPJP) will be developed for each individual Treatability Study Plan (TSP). Site-wide DQOs have been established and are presented in the QAPJP. However, it is more appropriate to establish DQOs on a site- and/or investigation-specific basis, based on the site specific characteristics and data needs of the investigations. Therefore, DQOs will be developed for each TSP and presented in the QAA that is</p>

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2	2	<p>representativeness, and completeness. The text should include these standards in the protocols for conducting treatability studies. Also the data quality objectives for site-wide treatability studies should be defined.</p> <p>Rationale: The implementation of an appropriate quality assurance/quality control (QA/QC) program is required to ensure data of known and documented quality are generated. The quality of treatability testing data required should correspond proportionately to the implications of the decisions that will be based on those data.</p> <p>Page 4-5, Section 4.1. While summarizing the general contaminants of concern at the site, the text should indicate significant levels of acetone and toluene have been detected. Acetone has been detected at various locations through the site, and at (200-300 micrograms/kilogram (ug/kg)) concentrations at operable unit (OU)2 in the vicinity of the mound areas. Similarly, toluene has been detected at concentrations as high as 860 ug/kg at OU1. These contaminants should be considered in the selection of technologies for treatability studies.</p> <p>Rationale: Acetone contamination is difficult to mitigate because it is extremely soluble in water. High concentrations of acetone in waste streams or treatment residuals could affect the selection of a particular technology for remedial action. Toluene can be mitigated with standard technologies for treatment of volatile organic compounds, but should be considered in the technology screening process.</p>	<p>developed for that particular TSP. The DOOs will establish acceptable measurements for accuracy, precision, comparability, representativeness, and completeness.</p> <p>The maximum concentrations of acetone and toluene detected site-wide in soils and sediments were below the ARARs presented in Table 4-2. The potential ARARs selected for acetone and toluene in soils and sediments are based on human health-based criteria for systemic toxicants (reference doses). These are as yet potential and not the final ARARs. Lower ARARs or action levels may be selected during the specific operable unit CMS/FS process. As part of the annual reporting process and OU-specific programs, the selection of technologies will be reviewed where new ARARs are selected or where additional contaminants need to be considered.</p>

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3	3	<p>Page 5-1, Section 5.0. The technology screening and selection process should evaluate performance, implementability, removal efficiencies, relative costs and operation and maintenance requirements of candidate technologies (Article XI, Attachment 2, IAG). Similarly, ARARs should also be identified, including land disposal restrictions, Clean Air Act, fugitive dust and emission standards, transportation regulations and design and operating standards.</p> <p>Rationale: The treatment technologies should be carefully screened and selected after evaluating all relevant criteria. ARARs, in particular, are threshold criteria for eliminating technologies early in the screening process. All ARARs should be identified before beginning treatability and feasibility studies. (Also see general comments 1 and 4.)</p> <p>These criteria have been added to the screening process. Potential chemical-specific ARARs were selected for use in this plan. These are not final ARARs, however, and will be subject to change during the CMS/FS process. Regulations such as those mentioned here which are not considered as ARARs in this Treatability Studies Plan, will be considered in the specific operable unit programs.</p>
4	3	<p>Page 5-3, Paragraph 1. The text lists three criteria for eliminating practical technologies from treatability tests. However, well-proven technologies should not necessarily be eliminated from laboratory or bench-scale testing during the screening process.</p> <p>Rationale: Laboratory and bench-scale tests are frequently used to evaluate specific waste types and waste streams with proven technologies. For example, biological treatment is well proven, but treatability tests are necessary to determine the waste stream toxicity and the removal efficiency of the treatment system for the specific waste.</p> <p>Practical technologies, along with innovative and emerging technologies were screened based on the same criteria. Several "well-proven" technologies were selected for testing.</p>

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5	3	<p>Page 5-4, Paragraph 3. The primary objective of the treatability program as stated is to demonstrate the effectiveness of a given technology in reducing contaminant concentrations. Technologies may then be screened to develop remedial alternatives. The data from the treatability studies also should demonstrate the implementability and cost of a given technology.</p> <p>Rationale: Effectiveness, implementability, and cost are the three criteria for technology screening and development of remedial alternatives. If the results from treatability studies are to provide necessary information for planning OU-specific programs, these criteria should be evaluated. (Also see general comment 1.)</p>
6	4	<p>Page 5-7, Section 5.1.2. Chemical specific ARARs should be identified and evaluated more carefully and included in the text. Similarly, location- or action-specific ARARs should not be deferred to full-scale implementation of the remedial alternative.</p> <p>Rationale: Chemical-specific ARARs establish the acceptable level of concentration of a chemical that may be found in, or discharged to, the ambient environment. For example, the national ambient air quality standards (NAAQS) under the federal and state clean air act are chemical-specific ARARs. Action-specific ARARs may affect the implementability of a particular technology at the site. Action-specific requirements do not in themselves determine the remedial alternative; rather they indicate how a selected alternative must be implemented. Location-specific ARARs may restrict the conduct of remedial activities or the concentration of hazardous substances solely because they are occurring in a particular place.</p> <p>Potential chemical-specific ARARs were identified for use in the screening of potential technologies in the Final Treatability Studies Plan (see Appendix A and Table 4-2). NAAQS were not included as potential chemical-specific ARARs in this plan in that the requirements related to attainment of NAAQS are ARARs only when the remedial activity is a "major source" of emissions. Emissions from CERCLA activities generally are not expected to qualify as "major sources" according to EPA guidance (EPA/540/G-89/009). Location and action-specific ARARs were not selected as they would provide little information how effectively a technology treats waste. Location and action-specific ARARs and any additional chemical-specific ARARs will be considered as part of the OU-specific CMS/FS program.</p>

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7	4	<p>Page 5-7, paragraph 1. The toxicity characteristic leaching procedure (TCLP) is included in the text as a potential ARAR. The TCLP is the method to identify Resource Conservation and Recovery Act (RCRA)-characteristic or -listed wastes. The TCLP itself is not a regulatory level or potential ARAR. This should be corrected in the text.</p> <p>Rationale: Correct usage of terms minimizes the potential for misinterpretation.</p>	This has been corrected in the text (see Section 4.2).
8	4	<p>Page 5-15, Section 5.2.1. For practical purposes, the contaminants at the site were divided into five major groups. The text should also identify indicator or target chemicals of concern within each contaminant grouping that will be used to screen technologies. Indicator chemicals are selected based on concentrations and common contaminant fate and transport characteristics.</p> <p>Rationale: Contaminant groupings are practical for preliminary identification of technologies. However, selection of technologies should also be based on effectiveness of treatment of indicator chemicals at the site. Treatability processes can be screened for a group of contaminants (for example, volatile organic compounds (VOCs)). However, individual chemicals will behave differently within that group. For example, toluene and p-xylene are relatively biodegradable, but o-xylene, m-xylene, and ethylbenzene are relatively undegradable. Similarly, trichloroethene is readily adsorbed on granular activated carbon, but vinyl chloride is only adsorbed in trace amounts.</p>	<p>The text has been revised to include the selection of target contaminants for use in the screening of practical technologies. Target contaminants were identified based on a review of maximum concentrations site-wide and a compilation of contaminants present at levels above ARARs in two or more operable units for groundwater surface water, soils, and sediments (see Section 5.2.1).</p>

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9	5	<p>The list of technologies for treatment of soil and groundwater has been greatly expanded. Treatment of output streams and side streams is only considered indirectly, since many of the technologies screened could be used for this purpose. Treatment of light and/or dense nonaqueous phase liquids was not considered because no data indicating their presence was available. Additionally, these liquids are not "treated", rather, they are generally removed from an aquifer in bulk using special equipment.</p>

Page 5-17, Section 5.2.2. This section identifies practical technologies and applications for treatment of the five categories of contaminants. However, the identification of the practical technologies for treatment of contaminants in soil and ground water is limited. The text should be expanded to include additional technologies and variations of listed technologies. Similarly, technologies for treatment of output streams and side streams generated as a result of treatment processes (for example, off-gas or aqueous effluent polishing from an air stripper) should be considered and listed in the text. Finally, technologies for treatment of light or dense nonaqueous phase liquids should be considered.

Rationale: There are additional practical technologies which have not been considered in the TSP. Practical technologies for water and soils that should also be considered are listed below. These technologies have all been demonstrated at full scale.

WASTE GROUP	WATER	SOILS
Inorganic contaminants	Thermal treatment - wet air oxidation - pyrolysis Carbon adsorption Neutralization	Thermal treatment In-situ chemical treatment Vitrification (in-situ or ex-situ) Solidification/stabilization
Radionuclides	Chemical extraction	Cement-based stabilization In-situ vitrification
Metals	Precipitation/flocculation/sedimentation Oxidation/reduction	Cement-based stabilization In-situ vitrification Soil flushing

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10	6	<p>Volatile and semi-volatile organic compounds</p> <p>Ultraviolet photolysis</p> <p>Incineration</p> <p>- liquid injection</p> <p>- rotary kiln</p> <p>- fluidized bed</p> <p>- pyrolysis</p> <p>Liquid-liquid extraction</p> <p>Microbial degradation (in-situ)</p> <p>Glycolate dechlorination</p> <p>Steam stripping</p> <p>In-situ vitrification</p> <p>Chemical extraction</p> <p>Glycolate dechlorination</p> <p>Pyrolysis</p>	<p>Cleanup goals are included as a criterion for the preliminary screening of treatment technologies in this Treatability Studies Plan (see Section 5.1.2). Although cleanup goals have not been set, potential cleanup goals were proposed based on the ARARs shown in Table 4-2 of the final document.</p>
11	6	<p>Page 5-27, Paragraph 3. The text states effectiveness refers to the ability of a technology to treat a given volume of waste based on cleanup goals. However, cleanup goals have not been set. Cleanup goals for contaminants or waste groups at the site should be defined in the treatability studies plan.</p> <p>Rationale: Evaluating effectiveness without knowing cleanup goals or desired removal efficiencies is not appropriate. (Also see general comment 3.)</p> <p>Page 5-28, Section 5.2.3. The rationale for selection or elimination of practical technologies for stage I treatability studies is not clear. With few exceptions, most treatment processes require treatability testing to determine the effectiveness for site-specific compounds, mixtures, and hydrogeologic conditions. Many conventional, demonstrated technologies require treatability studies to reduce cost and performance uncertainties for treatment alternatives to acceptable levels to support the selection of the alternative and remedial</p>	<p>Treatability testing to determine the effectiveness of site specific compounds, mixtures, and hydrogeologic conditions is better left to the OU-specific programs. This also applies to cost and performance optimization.</p>

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12	6	<p>design. For an area-wide technology evaluation, each candidate technology should be evaluated with respect to data needs and treatment goals for the site. Criteria should be defined for selecting practical technologies for treatability studies with respect to effectiveness, implementability, and cost for mitigation of specific contaminants at the site.</p> <p>Rationale: It is difficult to identify treatment technologies applicable to all contaminant groups or even all individual contaminants within a group. Treatability testing should generate information for site-wide target compounds. The best technology for specific contaminants and contaminant groups should be evaluated and combinations of the technologies can then be selected for effective remediation of contaminants throughout the site and each OU.</p> <p>Page 5-30, Paragraph 4. Granular activated carbon (GAC) adsorption should be considered for stage 1 treatability tests. GAC technology requires treatability tests to evaluate applicability to organic contamination on the site. For mixtures of contaminants known to exist at the site, liquid-phase adsorption isotherm tests should be performed. Subsequent dynamic column studies (batch tests) can be used to determine optimum contact time, mass transfer zones, and system configuration.</p> <p>Rationale: Treatability studies are necessary to evaluate the effectiveness, implementability, and cost of GAC technology for conditions at Rocky Flats.</p> <p>Granular activated carbon was screened per the established criteria.</p>

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13	7	<p>Page 5-31, Paragraph 2. Membrane processes such as reverse osmosis and electro dialysis should be considered for stage 1 treatability tests. Although these are demonstrated technologies for certain metals, they should be evaluated for specific conditions at Rocky Flats. For example, for an efficient reverse osmosis process, the chemical and physical properties of the semipermeable membrane must be compatible with waste stream characteristics. Simple (bench scale) treatability studies could evaluate the optimum membrane requirements (geometry, chemistry, pore size) for effective removal of contaminants at Rocky Flats. Finally, the text should indicate what water quality parameters (concentration limits) are required for testing of these processes.</p> <p>Rationale: Treatability tests are necessary to evaluate reverse osmosis and electro dialysis technologies for conditions at Rocky Flats.</p>	<p>Membrane processes such as reverse osmosis and electro dialysis were screened using the established criteria.</p>
14	7	<p>Page 5-31, Paragraph 5. In-situ and above ground biological treatment are conventional and commercially available technologies and should not be deferred to the innovative/emerging technology assessment. These treatment processes, although sufficiently demonstrated, still require treatability tests to predict biological toxicity in the treatment plant.</p> <p>Rationale: Biological treatment processes are well demonstrated and not innovative or emerging. These treatment processes almost always require treatability tests to evaluate effectiveness and implementability for site-specific conditions.</p>	<p>In-situ and above ground biological treatment were added to the screening list.</p>

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15	7	<p>Page 6-1, Paragraph 3. The text states DQOs levels II and III will be used for all treatability studies. However, DQOs for the treatability tests will vary depending on significance and magnitude of the study. The text should be corrected to indicate the DQOs will be established for individual treatability studies.</p> <p>Rationale: In general, analytical levels I and II apply to laboratory screening treatability studies, and analytical levels III, IV and V apply to bench- and pilot-scale treatability studies.</p>	<p>This comment is essentially correct. DQO's should be established relative to the desired end-use of the data. This should include an evaluation of requisite detection levels as well as Precision, Accuracy, Representativeness, Completeness, and Comparability (PARCC) parameters. Once this step is completed, the proper analytical technique and corresponding level (i.e., Level I, II, etc.) can be specified. It is possible that, upon completion of the DQO process, certain analytical techniques with corresponding level IV and V may be required, particularly with respect to radionuclides.</p>
16	7	<p>Page 6-1, Paragraph 4. The text implies that the median and average contaminant concentrations for waste distributions will be the same. However, this is not necessarily true, and in general, the median and average values will be different. The text should state whether treatability tests will be performed with waste containing either the median or the average concentrations.</p> <p>Rationale: Unless the concentrations are normally distributed, which is seldom the case with chemical analyte populations, the median will not equal the average (mean). It is important to differentiate between median and mean for treatability testing as they may be significantly different depending on the distribution of values.</p>	<p>The text has been corrected to read "average (mean) and high contaminant concentrations" (see p. C-1).</p>
17	8	<p>Page 6-2, Paragraph 1. The text indicates that multivariable analysis will be provided, where appropriate, on additional tests to supplement treatability studies. The text should indicate the types of multivariable analyses to be performed during additional tests.</p>	<p>This level of information will be included in the individual Treatability Study Work Plans where appropriate.</p>

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18	8	<p>Rationale: The utility of providing multivariable analyses (where appropriate) is not clear without the identification of specific tests.</p> <p>Page 6-5, Paragraph 2. While discussing the test approach for oxidation/reduction(redox) treatability studies, the text should specify the need for sampling waste stream and side stream residuals for evaluation during screening and selection. The text should indicate the need to identify/characterize the disadvantages and limitations of a particular process in addition to its effectiveness.</p> <p>Rationale: Chemical redox is an indiscriminant process and can result in incomplete reactions or unwanted side reactions. When using chemical redox techniques with chlorinated organic compounds the possibility of producing hydrochloric acid exists. Leach tests will need to be conducted or residual solids to determine the need for stabilization, and the liquid effluent should be analyzed to determine the need for further treatment.</p> <p>This will be discussed in the detailed Treatability Study Work Plans.</p>
19	8	<p>Page 6-8, Paragraph 2. The TSP considers soil washing for organic compounds an innovative/emerging technology. However, soil washing for organic compounds is a demonstrated, practical technology and should be part of the TSP.</p> <p>Rationale: Soil washing for organic compounds has been effectively demonstrated using alkaline agent, surfactants, and biodegradable polysaccharides.</p> <p>The TSP no longer specifically distinguishes between "Practical" technologies and "Innovative/Emerging" technologies.</p>

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20	8	<p>Page 6-12, Paragraph 1. The test objectives of the solidification/stabilization treatability tests should include determination of the waste-to-additive ratios, mixing and curing conditions. The short-term environmental impact of stabilizing wastes may be small, but long-term reliability is not well known. Provisions for monitoring all applicable parameters for the technology screening process should also be included in the objectives.</p> <p>Rationale: Leachate produced as a result of the curing process should be collected and analyzed. The heat generated by the curing or stabilization can drive off volatile organic compounds and may necessitate gas monitoring or screening. The determination of optimum waste-to-additive ratios, mixing, and curing conditions should be primary considerations during the treatability study.</p>	<p>This will be addressed in the detailed Treatability Study Work Plans.</p>
21	9	<p>Page 6-16, Paragraph 2. Phase 2 of the biological treatment treatability study should also establish optimum slurry densities, pH, temperature, and residence time. The need to monitor these parameters should be included in the statement of work.</p> <p>Rationale: The treatability study should monitor all parameters which are used to evaluate a technology in terms of implementability, cost, and effectiveness for technology selection and design.</p>	<p>Biological treatment technologies did not pass the final screening.</p>
22	9	<p>Page 7-1, Section 7.0. This section discusses schedules and deliverables for the treatability studies program, but only includes practical technologies. Schedules and deliverables for emerging/innovative treatment technologies treatability studies and treatability study work plans should be included.</p>	<p>The TSP no longer distinguishes between "practical" technologies and "innovative/emerging" technologies.</p>

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		<p>Rationale: The evaluation of emerging/innovative technologies is an integral component of the treatability studies or Rocky Flats, but is not included in this document. Based on existing information, the treatability study plan should provide a statement of work for evaluating candidate technologies. This includes innovative/emerging technologies. Examples of these technologies from the Superfund Innovative Technology Evaluation (SITE) program are membrane microfiltration, solvent extraction, plasma reactor, infrared thermal destruction, and freezing separation. (Also see general comment 2.)</p>

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1	1	<p>General Comments. As indicated in verbal comments provided during the meeting held November 27, 1990, the separation of the Treatability Study Plan (TSP) into two documents is inconsistent with the IAG requirements. A plan for identifying, testing and evaluating innovative and alternative technologies must be incorporated in this document. This should include both innovative technologies which show a potential to address problems for which conventional treatment options do not exist and technologies which may offer improved performance or cost advantages over those currently in use. Preparation of the plan must include a thorough review of available literature and ongoing work within DOE and elsewhere. Results of efforts completed at RFP for other purposes (such as TARs) should be incorporated as appropriate.</p>	<p>The TSP has been expanded and revised to include innovative and emerging technologies. Review of literature and ongoing work within DOE and EPA has been included. Screening criteria includes whether or not a technology includes advantages over more conventional, proven technology.</p>
2	1	<p>Various sections of the TSP discuss Future Treatability Study Workplans, Treatability Study Work Plans, Executable-level Plans, and Scopes of Work. These terms are not clearly defined or consistently used, so it is unclear what documentation will be prepared before work begins on a particular study. The TSP should define this clearly and propose a means by which EPA can participate in the scoping and planning process for each study.</p>	<p>Text has been revised.</p>
3	1	<p>The discussion of the role of the sitewide program and its interface with OU-specific treatability studies provided in the Program Objectives is not reflected in later sections. The objectives indicate the site wide program will reduce, often eliminate the need for OU-specific studies. The scopes of work provided for the five studies identified appear to defer everything beyond rudimentary jar testing to the OU-specific studies; this is not necessary or appropriate. Any testing, including bench and pilot scale, which addresses a problem reasonably expected to occur in more than one OU should be conducted under the sitewide program.</p>	<p>The discussion on the role of the sitewide program and its relationship with OU-specific studies has been greatly expanded (Section 3.1). Criteria for sitewide studies now is based on two or more OUs. Proposed testing, however, for the sitewide program is limited to lab/benchscale testing at this time. Pilot testing, which is generally used for obtaining design information for a specific application will be reviewed after completion of the bench tests and after additional review of technology data, contaminant data, and ARARs.</p>

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4	1	<p>Several sections of the TSP address the question of compliance with and preparation of other program documents. In many instances the terminology used is inconsistent and the text provided indicates general confusion over how all these documents fit together. These passages must be revised in accordance with verbal comments provided for the TSP and written comments on the SOPs and QAPJP; all treatability testing must be performed within the SOP/QAPJP framework, and test-specific documentation (SOPs/QAAs) provided as needed.</p> <p>The schedule information provided is incomplete and internally contradictory in some respects. A detailed schedule must be provided to show the various studies to be performed and the sequence of events leading to meeting established deliverable deadlines. Use of a larger scale and inclusion of more detail on the bar charts would help a great deal.</p>
5	1	<p>All treatability tests will be performed within the SOP/QAPJP framework. Section 6.2.11 now explains the relationship between the site-wide QAPJP and TSP-specific QAAs. QAAs will reference the applicable SOPs and any SOPs that will be adhered to during the conduct of the treatability studies.</p>
1	2	<p>The TSP has been revised to better explain the screening process utilized and the how and why of the final selection. Numerous tables (Tables 5-3 A, B through 5-8) have been added to further clarify the process.</p>

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2	2	<p><u>Specific Comments</u></p> <p>Executive Summary. The TSP must present a scheme for evaluating the effectiveness of both innovative and emerging technologies as well as practical technologies which have a potential application to Rocky Flats (RF). The intent behind the language requiring delivery of the TSP within the proposed Interagency Agreement (IAG) is to utilize the literature to identify both practical and innovative technologies which have potential applicability to RF problems. The purpose of testing both innovative and practical technologies is to narrow the focus of the site specific treatability tests and support the site specific feasibility studies. All technologies potentially applicable should have been preliminarily identified through a search of the literature. Preliminary selection of potentially advantageous technologies should be predicated upon advantages in implementability, fewer adverse impacts than other available approaches, less process waste, or lower costs for similar levels of performance, in addition to the standard selection criteria of cost, effectiveness and implementability. The preliminary screening should have been completed as a prerequisite to developing this plan and should have included an evaluation of all emerging and innovative technologies as well as the practical and proven technologies. The proposed IAG does not anticipate more than this submittal.</p> <p>After developing this preliminary list of emerging and practical technologies, all technologies identified must then be carried through the screening process defined within this TSP.</p>
3	2	<p>The revised sitewide treatability study work plan will incorporate both practical and innovative/emerging technologies consistent with the requirements.</p>

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1	3	<p>Treatability Study. Treatability studies for both practical and innovative/emerging technologies must be included in this document.</p> <p>Section 1.0, page 1-5. Fig 1-2 presents a schedule for sitewide treatability studies and OU specific feasibility studies. It is important to acknowledge that treatment activities ongoing for a specific OU, may have application in more than one particular OU and impact the direction taken within the sitewide treatability studies plan.</p> <p>This figure has been deleted. A new figure (Fig. 7-1) is included which specifically addresses the sitewide TSP only. Provisions will be made for adding new technologies to the sitewide program, if appropriate.</p>
2	3	<p>Section 3.0, page 3-1. Treatability studies may also identify data voids which need to be filled through implementation of RFI/RI workplans in order to quantitatively evaluate the effectiveness of a technology preliminarily evaluated within the scope of the TSP.</p> <p>At this time it is not known in detail what data gaps exist for each operable unit. The sitewide plan will not itemize every data gap for each operable unit. These gaps will be identified during the OU specific treatability programs.</p>
3	3	<p>Treatability study workplans for each treatability study to be conducted should also include a section addressing the potential for additional work needed to fill any site characterization data gaps. In other words, information on additional field sampling work and quality assurance potentially necessary to fully evaluate an applicable technology should be included within the treatability study work plan so that the RFI/RI Workplans can be modified or focused to present the proper supporting information.</p> <p>As is not stated in Section 6.2.11, a Quality Assurance Addenda (QAA) to the sitewide Quality Assurance Project Plan (QAPJP) will be developed.</p>

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		<p>The FSP and QAPJP are not conducted within the sitewide treatability studies program and they should not be modified to meet the needs of each treatability study.</p> <p>The meaning of the third item in the dot-list is not clear, since the documents referenced are not "conducted within" the subject program. The final, and overall, objective is to prepare a comprehensive Sitewide Treatability Study report for use as a basic reference document in the completion of Feasibility Studies.</p> <p>Section 3.1, page 3-3. Given the extended timeframe between approval of this plan and the required submittal of the Treatability Studies Report, it seems that the TSP schedules could be adapted to provide information pertinent to the priority OUs and that preliminary reports could be published to provide the important information to the preparer of the CMS/FS reports for those OUs which are scheduled to get to the CMS/FS stage sooner than others.</p> <p>Section 4.0, page 4-1. The data presented in this section needs to be updated to present the most recent sampling and analyses. This is important as much of the data collected prior to 1988 is of questionable validity and may in fact not represent contamination on the site.</p> <p>The data presented within the tables must not be prejudiced by unsupported conclusions regarding the presence or non-presence of various constituents whose presence is still a point of contention.</p> <p>Section 5.0, page 5-3. The text indicates an interest only in laboratory and bench-scale testing; this is only a small part of the treatability testing program that needs to be described. Reference is also made to "other databases" showing results</p>
4	3	<p>The third item in the dot-list has been revised to read "review and modify, as required, the FSP and QAPJP."</p> <p>Both interim and annual reports will be prepared to facilitate transfer of information.</p>
1	4	<p>The data presented in Table 4-1 in Section 4.0 of the draft report have been completely updated and are the most recent available (as of April 1991) from the 1990 and 1991 source documents. These source documents are listed in Table 4-1 of the April 22, 1991 Final Treatability Studies Plan. The data themselves are presented in Table 4-2 of the final report. Only data for those chemicals reported to have been detected in these recent documents are presented in Table 4-2.</p>
2	4	<p>The sitewide treatability study program is limited to only laboratory and bench scale testing. Pilot testing will be conducted during OU specific treatability studies only. A more concise description of the databases is included in the revised plan.</p>

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3	4	differing from those included here. A better description is required of where the data came from and how it was manipulated. Section 5.0, page 5-4. In the paragraph beginning "The technology evaluations" it is not at all clear how the approach described in the second sentence facilitates accomplishment of the goal stated in the first.	Section 5.0, Technical Approach has been modified to present a concise approach to identify and screen the technologies for inclusion in the sitewide program.
4	4	Section 5.1, page 5-5. The technology assessment report identified within this section must be submitted with the ISP as this report documents the selection process. Submittal of this report will aid an evaluation as to whether all the available options have been considered and to justify selection of the to be tested alternatives.	Text has been revised to delete reference to a Technology Assessment Report.
5	4	Section 5.1.3, page 5-9. Final decisions regarding the implementability or effectiveness of a selected technology which has application to more than one OU, should also be considered in a subsequent step internal to the sitewide treatability studies program and not just in the individual OU CMS/FS.	The sitewide program will overlap certain OU-specific programs. Final decisions on implementability or effectiveness of selected technologies are not appropriate for the sitewide program and will be considered in the OU specific programs only due to scheduling constraints.
4	4	Section 5.1.5, page 5-13. This section states that innovative technologies were not considered due to the limited site characterization data currently available. Site characterization data needed to fill data gaps can be collected during the RI/FS Treatability Studies process. Therefore, innovative technologies should also be considered at this stage of the treatability studies.	Both innovative technologies and practical technologies are included in the revised plan.
5	4	Section 5.2, page 5-14. This section presents the results of the technology selection process for practical technologies. Documentation of the process used to select the alternatives is	The report has been revised to better explain and document the selection process, which now includes innovative technologies.

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1	5	<p>essential to approving this document. It is also mentioned that a similar technology assessment report will be issued for innovative technologies. This report must be a part of the TSP.</p> <p>The document must justify the selection of only five technologies. What were their advantages over the others?</p> <p>Section 5.2.3.1, page 5-27. In section 5.1.2 it was mentioned that chemical specific ARARs will be used as another screening tool. However this section only considered three criteria: effectiveness, implementability and cost. At this stage of the screening process chemical specific ARARs must be also considered.</p> <p>Section 5.2.3.2, page 5-28. Where is the documentation of the selection process? Why were only five technologies selected and not more? The process of applying the selection criteria which the first sentence here says took place is what must be presented completely and in detail. The "rationale for the selection or elimination" presented in the next few subsections is the only support the document provides for the selection decisions. It is vague, unsubstantiated, and incomplete. No mention at all is made of at least half the candidate technologies listed in Table 5-2.</p> <p>Table 5-3 does not present any technologies to be tested to evaluate treatment for organics in water. It is true that there are technologies available that have been proven successful for removing organics in water. However, this is not a valid reason for not considering treatability studies on innovative/emerging technologies to address this problem. It is possible that a new technology may offer a higher level of performance, at less cost, available at this moment.</p> <p>Chemical specific ARAR's are included as a screening criteria in the revised plan.</p> <p>A major revision was done to the sitewide treatability study plan. It now provides a documented identification process along with the rationale for the selection or elimination of treatment technologies.</p> <p>The approach for identifying and screening applicable technologies has been modified in the revised plan to include innovative technologies and criteria to evaluate innovative technologies.</p>

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3	5	Section 5.2.3.3, page 5-30. It is important to mention which proven technologies are planned to be used at RF. For example, carbon adsorption and membrane processes have been already selected as an IM/IRA for OU2.	The proven technologies that are planned to be utilized at RFP only apply to OU1 and OU2. These applications are noted.
4	5	Section 5.2.3.4, page 5-33. This section states that in-situ biological treatment will not be considered for treatability studies at this time because more specific site hydrogeologic data needs to be collected. This technology should not be eliminated from consideration for this reason. There exists hydrogeologic data for some OUs, for example, the solar ponds, OU1 and OU2.	The applicability of in-situ bioremediation is a function of contaminant type and site specific conditions. It would be inappropriate to evaluate in-situ bioremediation on a sitewide basis. In-situ bioremediation will be considered only during the OU specific programs.
5	5	Section 5.2.3.5, page 5-33. Oxidation/reduction methods for inorganics, metals and radionuclides in water were selected in this initial stage of treatability studies. This is not presented in Table 5-4 on page 5-34. This inconsistency must be corrected.	This inconsistency has been corrected.
1	6	Table 5-4, Page 5-34. The information displayed here does not agree with the text or with Table 5-3. Also classification of "Stage I" studies as opposed to "Future" doesn't carry over to the next section, where "Future" apparently means something else.	Table 5-4 has been deleted.
2	6	Section 6.0, page 6-1. The assertion made in the first sentence of this section is false; some "Statements of Work" are presented along with guidelines for Work Plans. The workplans themselves do not appear, nor should they. The "Scopes of Work" are so skeletal as to be of little use, and it is not clear what purpose they serve in this context.	The individual statements of work are included in Appendix C. Their primary intent is to provide general guidelines for scoping the actual workplans.
3	6	Section 6.1, page 6-1. FSP and QA/QC procedures specific to the treatability studies to be conducted must be included in the treatability studies workplan and as addenda to the generic FSP and QA/QC procedures.	EG&G Standard Operating Procedures (SOPs) for IAG required activities have been submitted to EPA and CDH for review and approval. These SOPs and the QAPJP together comprise the SAP required by the IAG. The SOPs include field sampling procedures and appropriate QA/QC procedures.

**ROCKY FLATS ENVIRONMENTAL RESTORATION PROGRAM
REVIEW/COMMENT RESOLUTION FORM**

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Reviewer Name(s): ENVIRONMENTAL PROTECTION AGENCY Date:

REVIEWER'S COMMENTS		RESPONSE
COMMENT NO.	PAGE NO.	DISCUSSION
		<p>Additional QA/QC controls are included in the QAPJP. Where the implementation of a treatability study requires the use of an SOP or QA/QC control described in the QAPJP, the specific SOP or QAPJP will be referenced, but not included, in either the work plan or the quality assurance addendum, or both. Any sampling or QA/QC procedures that are specific to the treatability study will be included in the work plan for each TSP. The sitewide SAP, which consists of the SOPs and QAPJP, will not be modified, since, as you correctly point out, these are generic documents that address all IAG activities.</p> <p>The justification to determine the level of treatability testing has been included in the revised sitewide plan.</p> <p>There are potentially thousands of reaction mechanisms that could be encountered with the wide variety of organic contaminants present on a sitewide basis. Specific reactions will be delineated for OU specific treatability studies if appropriate.</p> <p>Appropriate references have been included in the revised plan.</p> <p>The third phase of testing is designed to optimize conditions for a specific waste treatment. One set of optimal conditions would not be applicable to the wastes on a sitewide basis. This third phase type of testing will be conducted only during the OU specific programs.</p>
4	6	<p>Section 6.1.1.1, page 6-2. The level of treatability studies (laboratory, bench or pilot scale studies must be justified. For example, in this case, bench scale was selected to be appropriate because the chemistry of the process was to be studied.</p>
5	6	<p>Section 6.1.1.3, page 6-3. It would help to present the reactions expected to take place for each of the oxidation and reduction processes in order to fully understand the chemistry. This will help in evaluation if the expected reactions are likely to occur, and will also allow evaluation of whether any adverse reactions may occur.</p>
6	6	<p>Section 6.1.1.3, page 6-4. The chemistry of plutonium is very complicated. It would help to list in the reference section the sources used to gather information.</p>
7	6	<p>Section 6.1.3.3, page 6-10. Why is the third phase to be conducted as part of CHS/FS for a specific OU? This is a technology that has application to more than one OU. The treatability studies should be conducted as part of the sitewide treatability studies.</p>